LABORATORY LESSONS

IN

PHYSICAL GEOGRAPHY

BY

LU LESTER EVERLY, M.A.

DEPARTMENT OF GEOGRAPHY, STATE NORMAL SCHOOL, WINONA, MINN.

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CALVIN L. WALTON, Ph.D.

TEACHERS OF PHYSICAL GEOGRAPHY IN THE CHICAGO HIGH SCHOOLS

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W. P. 1

CONTENTS

Exercises marked with a * may be chosen by schools that cannot give a full year to the subject.

THE ATMOSPHERE

THE OCEAN

PREFACE

The exercises presented in this manual are intended to be sufficient for a full year's work, but they are so written that some may be omitted by classes that have not time for all, without detriment to those remaining. It is intended that the pages of questions and directions be bound with the answer papers in the notebook. In some exercises where the answers are short, blank spaces are left on the printed page that the answers may be written immediately after the questions. The "loose leaf" plan of binding gives opportunity not only for the omission of exercises not needed, but also for the insertion of such other exercises as any teacher may choose to give. To the same end, and also that the exercises may be taken in the order in which the topics are studied, the exercises are not numbered. Reference may be made to them by the page numbers at the bottom of the page. Pupils should preserve all their papers, and at the end of the course arrange them in order, number the pages at the top, and write on the Table of Contents sheet (pp. 191, 192) the number, name, and pages of each exercise. The teacher will probably wish to examine and comment on each exercise as soon as it is done. The binding margin is a convenient place for marks, and also for the pupil's name, but the pupil must be careful not to let his writing run into this margin.

Some of the exercises require heat, water, and considerable apparatus — not always to be had at each pupil's desk. It is suggested that such exercises be assigned, the day before they are to be done, to several pupils, who shall have the preparations complete, and perform the experiments in the presence of the class. All members of the class should then write up the exercise. Most of the exercises have questions at the end called "Advanced." These questions are usually more difficult than those preceding, and are intended for the rapid workers who finish the main questions before the majority of the class are through.

A valuable service of the geographical laboratory is to give concreteness and location to the general principles taught in the text-book, and so the authors have tried in the manual to cover nearly all the topics treated in the common text-books of physiography. In the selection of contour maps care has been taken to choose those that clearly show the purpose of the exercise. Some of these maps, by their recognized merit, have become almost classic; it is hoped their value will be increased by the new setting given them. A certain uniformity of treatment, suggested by the headings in prominent type, has been followed wherever practicable, thus avoiding a haphazard way of approaching the problem.

A Standard Scale for cross profiles has been used wherever possible in order to simplify the comparison of regions. The horizontal scale is the same as that of the sheet where the ratio is 1/62500, and the vertical scale is 1 cm. = 100 ft. This gives a vertical exaggeration of about twenty. In regions of great relief a scale giving no vertical exaggeration is used. The great value of the "sea-level" profile is to show the altitude of the region. The space between the profile and the sea level should be shaded, or filled with the proper rock symbols.

The authors recognize the fact that the few years during which the laboratory has been used as a help in geography teaching have not been sufficient to bring the methods to perfection. Their ambition has been, not to write a book that shall stand permanently as an ideal in geography teaching, but to arrange some exercises that shall suggest better methods to many teachers, and save time for those who are too busy to work out the details of plans they may have had in mind. Criticisms and suggestions, looking to the elimination of errors or to the introduction of new material, will be welcomed by the authors. The exercises here given have been used in the class room for several years, and the authors are under obligations to their fellow-teachers for many valuable suggestions. The work has been tested in the class room again and again, rewritten where experience has shown it defective, and, it is hoped, will now be found suited to the needs of the pupil.

The following Maps and Apparatus are needed for the full set of exercises given in this book.

For exercises done as demonstrations before the class, one set of apparatus will be sufficient. For the exercises which each pupil is to work out fully, all the material required (globe, maps, minerals, etc.) will be needed by each pupil.

Apparatus marked with a * will be needed for the shorter course, and for a class of 15 pupils can be secured at a cost not to exceed $25.

Topographic maps, published by the U. S. Geological Survey, as follows: —

* Arizona — Kaibab
California — Cucamonga
* Shasta Special
Colorado — Anthracite
Lamar
Illinois — Chicago Folio No. 81
* La Salle
* Ottawa
Iowa-Illinois — Savanna
* Kansas — Caldwell
* Louisiana — Donaldsonville
* Maine — Boothbay
Maryland-Va. — Wicomico
* Minnesota — St. Paul
* New Jersey — Atlantic City
New York — Niagara
New York — Watkins
* North Dakota-Minn. — Fargo
Oregon — Port Orford
* Pennsylvania — Harrisburg
* West Virginia — Charleston
* Wisconsin — Whitewater

Maps published by the Mississippi River Commission, St. Louis, as follows: —

Sheet 14, or Sheet 18, of the Mississippi River Survey.

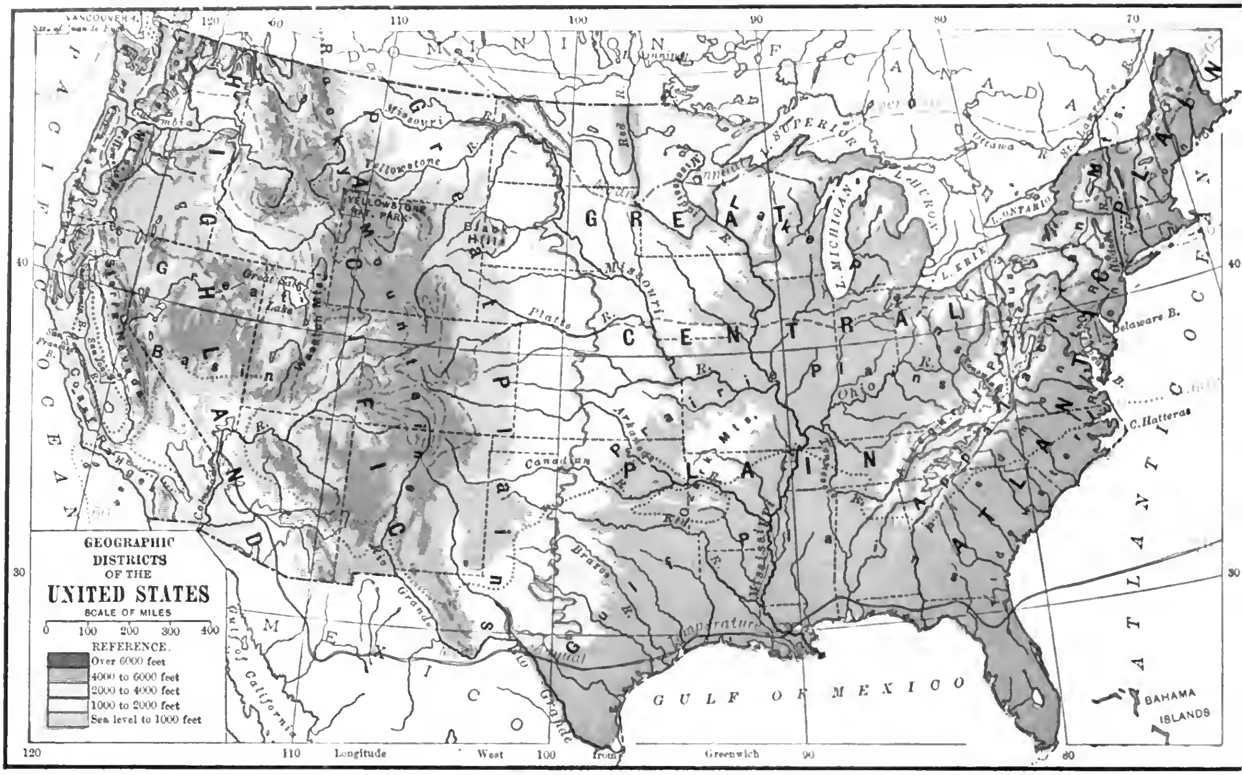
Map of the Alluvial Valley of the Upper Mississippi River.

Map of the Alluvial Valley of the Mississippi River from the head of St. Francis Basin to the Gulf.

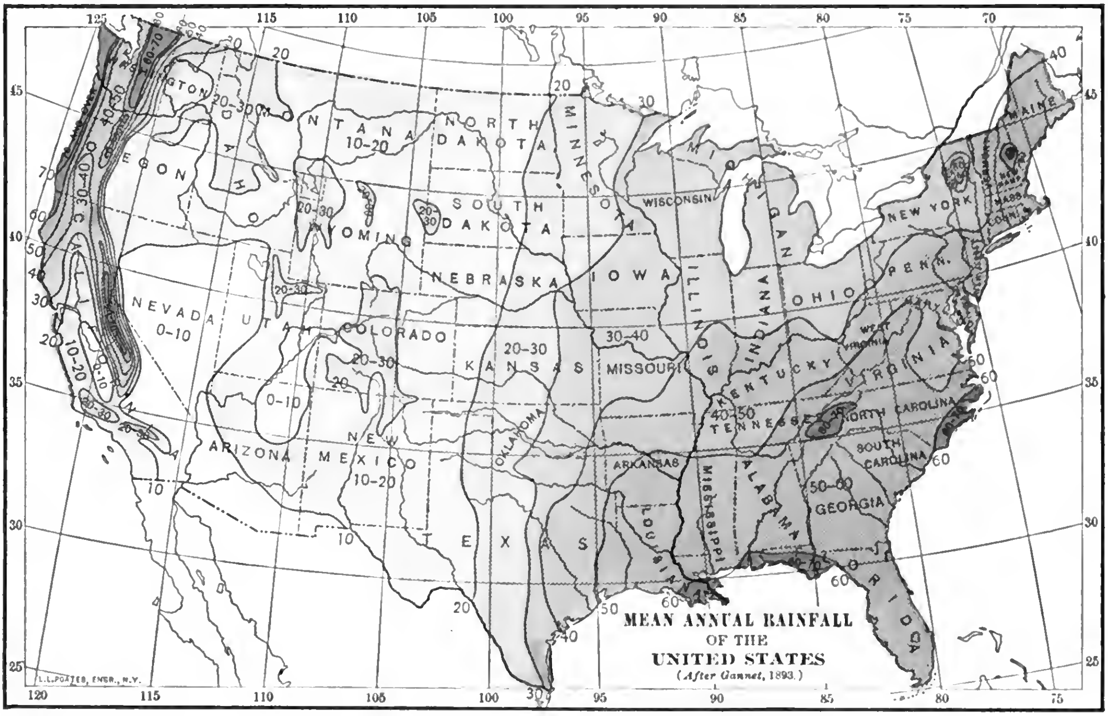
Pilot Charts of the North Pacific
Pilot Charts of the North Atlantic } (a summer month and a winter month; pp. 151, 184).

Bound sets of weather maps.

* Drawing compasses.
* Colored pencils or water colors.
* Ruler marked in inches and in centimeters.
* Protractor.
* A six-inch globe.
* A rubber band $\frac{3}{16}$ inch wide to encircle the globe.
A horizon disk (p. 23).
* A small ball with smooth unmarked surface.
Copper or brass gauze (p. 41).
3 shallow pans (p. 34).
1 long shallow pan.
Blotters.
* Steel knitting needle.
Sewing needles.
* 1 doz. small wooden blocks one inch thick (p. 48).
Metal ring and solid brass ball (p. 135).
Metal rod two feet long.
Wax or paraffin.
Candle.
Touch paper (p. 137).
Thread — coarse and very fine.
2 Argand lamp chimneys.
* Dentists' rubber.
* Small mirror.
Bright tin cup.
* Hand magnifier.
* ½ doz. 6-inch test tubes.
½ doz. 10-inch test tubes.
3 large test tubes, perforated bottom (p. 34).
* Assorted glass tubing.
* T tube ¼ inch.
* Rubber tubing.
Glass funnel.
Mason pint jar.
Erlenmeyer flask.
* 3 wide-mouth bottles with one- and two-hole rubber stoppers.
Vial.
Air thermometer.
* Thistle tube.
* Glass plates.
* Glass tumbler.
* Glass cup (pp. 121, 123).
* Glass prism.
* Barometer tube.
* 3 lbs. mercury.
2 bar magnets.
Iron filings.
* Air pump or bicycle pump.
Two-ring iron support.
* 2 thermometers of same size.
A chemical balance.
* Limewater.
Sodium peroxide.
Sulphuric ether or alcohol.
Potassium hydroxide.
Pyrogallic acid.
Hyposulphite of soda.
Alum.
* Dilute hydrochloric acid, acid bottles, and glass rod.
Pieces of marble.
* Specimens of the following minerals and rocks: quartz, feldspar, mica, hornblende, calcite, and others if desired (p. 30); coarse granite, gneiss, limestone, marble, sandstone, quartzite, shale, slate, and miscellaneous rocks.
* Various kinds of coal.
Iron ores (p. 36).
Rich black soil, sand, clay, unweathered till.
* Glacial pebbles, water-washed pebbles.
Molding sand, modeling tool, and sand tray (see p. 45).



GEOGRAPHIC DISTRICTS OF THE UNITED STATES



MEAN ANNUAL RAINFALL OF THE UNITED STATES
(*After Gannet*, 1893.)

A GLOBE EXERCISE

Purpose. To study latitude and longitude, etc., on a globe representing the rotating earth.

Material. A small globe, a pair of compasses, a ball with smooth surface unmarked.

Questions (Answers to be written on note paper of about the same size as this sheet; see Preface.)

1. Has the smooth ball lying still on the desk a diameter? A circumference? An axis? An equator? Poles?

2. Spin the ball as you would a top. Which of the above-named features has it acquired by rotation?

3. What is the name of the line on which the ball rotates? Where are the poles? Where is the equator?

4. On the globe note two sets of reference lines (fine, black) drawn as a convenience in designating the location of places. In what directions do these lines run?

5. The meridians (north-south lines) end in what points?

6. They are how many degrees long?

7. How many meridian lines are drawn on this globe? How many could there be in imagination? Into how many equal spaces do those drawn divide the surface of the globe?

8. How many degrees wide is one of the meridian spaces? How many miles wide at the equator? At the pole?

9. Set the compasses at the width of a meridian space at the equator. At what latitude does this equal the width of two meridian spaces? How many miles in the 360 degrees of longitude at this latitude? How many miles in one degree of longitude here?

10. The meridians are numbered along the equator. Beginning at the north, name in order the seas and countries through which the prime meridian (numbered 0) passes. What large city lies on the meridian?

11. Place the globe with the prime meridian toward you. Is east longitude toward your right hand or your left?

12. Name in order, beginning at the prime meridian and going east, the countries and oceans crossed by the equator.

13. The distance between the equator and the pole is divided into how many bands of equal width by parallel circles around the globe? How many degrees wide is each band?

14. From what line is latitude reckoned? What is the greatest number of degrees of latitude possible on the globe? At what places?

Advanced Questions. 15. Suppose it is noon January 1, 1907, at London; count eastward the meridian spaces (each 15° represents one hour in the afternoon); what is the time at 180°? Count westward the time before noon; what is the time at 180°? What difference in time do you get at 180° by the two counts? The international date line "where the day begins" follows the meridian of 180° in the main, passing, however, through Bering Strait and west of the Aleutian Islands.

16. Find the parallel circles (drawn in broken lines) that mark the zone boundaries, and give their names in order, beginning at the north. How many degrees from the equator to each tropic circle? To each polar circle? How many degrees wide is the torrid zone? Each temperate zone? How many degrees from the edge to the center of each frigid zone? Name the waters and countries through which each zone boundary passes.

17. Give the latitude and longitude of each of the following places: Washington, Chicago, San Francisco, London, Rome, Tokio, Cape Horn, Cape of Good Hope, Cape Farewell.

THE GLOBULAR PROJECTION OF THE WESTERN HEMISPHERE

Purpose. To represent in a plane the curved surface of half a sphere.

Material. Drawing compasses, a medium-hard sharp pencil, a ruler, a small globe.

On an accompanying sheet of paper is a circle six inches in diameter to represent the circumference of the globe, a straight line to represent the equator, and another at right angles to this to represent the central meridian. Through the three points next above the equator marked on the central meridian and on the circumference, draw an arc to represent 10° N. latitude. Through the next three points draw another arc to represent 20° N. latitude; and so on. These arcs may be drawn free-hand, or, if you have a suitable compass, set one leg in the line of the central meridian extended, at a distance of 24 inches from the 10° points and draw the arc. For each new arc you will have to take a new radius; for 20° take $11\frac{3}{4}$-inch radius; for 30°, 7 inches; 40°, $4\frac{13}{16}$ inches; 50°, $3\frac{1}{4}$ inches; 60°, $2\frac{1}{5}$ inches; 70°, $1\frac{1}{3}$ inches; 80°, $\frac{5}{8}$ inch.

Draw the corresponding lines south of the equator.

For the tropical circles (latitude $23\frac{1}{2}$°) use a radius of $9\frac{1}{2}$ inches; for the polar circles (latitude $66\frac{1}{2}$°), a radius of $1\frac{2}{3}$ inches. Draw colored or broken lines to represent these circles.

Through the poles and each point marked on the equator draw a meridian; free-hand or with compass (one leg in the equator line) set as follows: for the meridian nearest the central, $9\frac{1}{4}$-inch radius; for the next, 5-inch radius; then $3\frac{3}{4}$ inch; $3\frac{1}{4}$ inch; and $3\frac{1}{16}$ inch. If the meridians are drawn free-hand, draw the second from the center first; then the fourth, bisecting the space in which it is drawn; the first, third, and fifth each bisecting its space. Number the meridians along the equator, beginning at the right (east), 0°, 15°, 30°, etc., up to 180° at the west margin. Along the east and the west margin number the parallels 0°, 10° N., 20° N., etc., and 10° S., 20° S., etc., and write the names of the tropical and the polar circles.

Find on the globe the latitude and the longitude of the south point of Florida, the mouth of the Mississippi River, and the point of Yucatan. Locate these points on your map by means of your latitude and longitude lines, and with these points for guides draw the outline of the Gulf of Mexico. Get the latitude and the longitude of a point in Nova Scotia, in Labrador, etc. Locate these points on your map and sketch in the east coast of North America. In the same way fix several guide points in the west coast of North America, and in the coast of South America, and complete the outline of the western continent.

Questions. 1. One half inch on the equator of your map represents $\frac{1}{24}$ of the earth's circumference; how many miles does it represent? One half inch for this number of miles may be taken as the scale on which the map is drawn.

2. Will $\frac{1}{2}$ inch represent this number of miles along the central meridian?

3. Will $\frac{1}{2}$ inch represent this number of miles along the most easterly and the most westerly meridians?

4. The 60° parallel on the globe is just half the length of the equator; is the curved line 60° on your map just half as long as the equator?

5. Considering the questions above, what parts of your map are true to the scale? What parts are inaccurate?

6. What angles do meridians make with parallels on the globe?

7. Where on your map do the meridians make this angle with the parallels?

8. On the globe, is the distance between two parallel circles everywhere the same?

9. Is it so on your map?

10. Hold your pencil along the central meridian of your map. In what direction does it point?

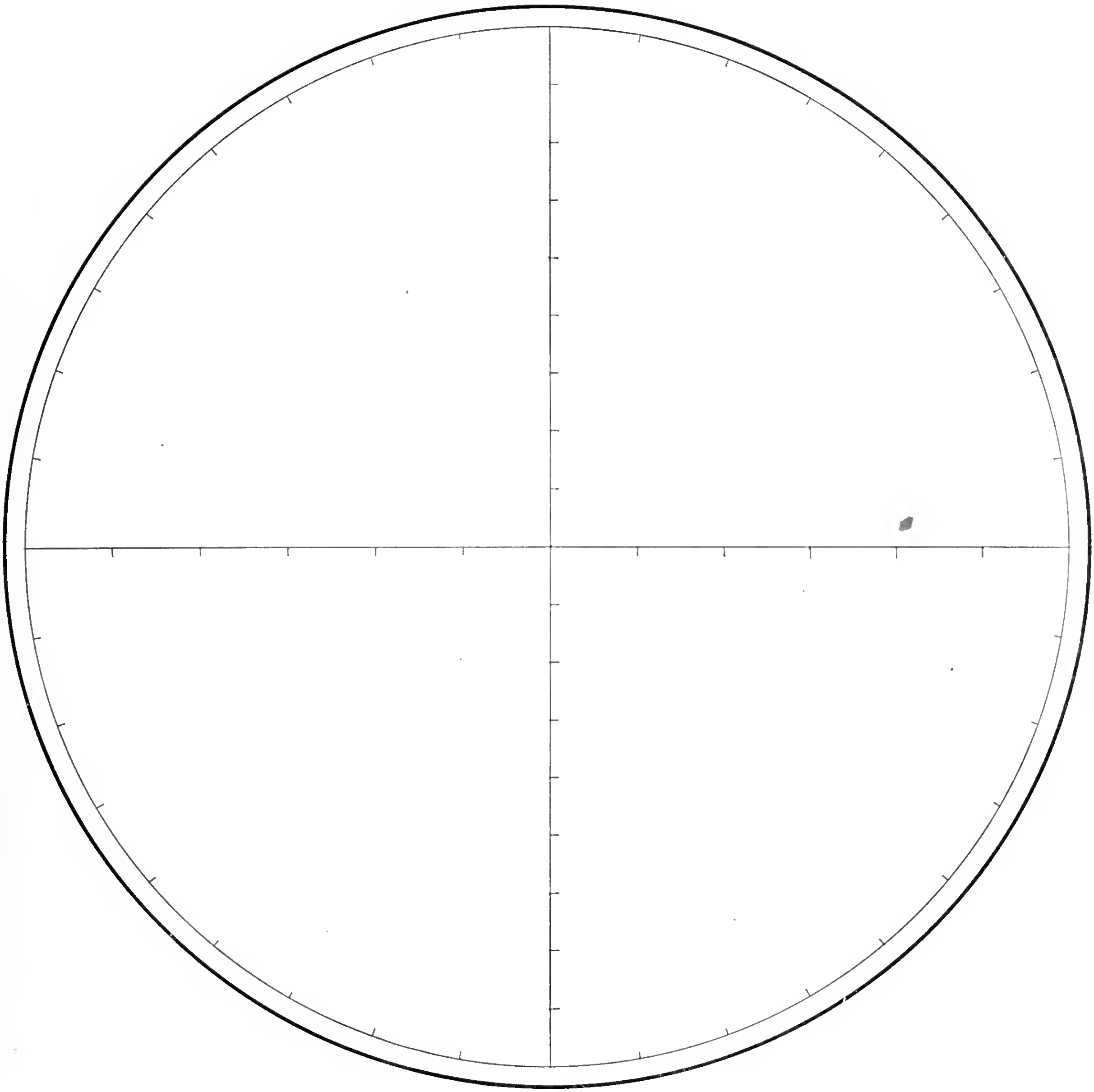
11. Slide the pencil slowly to the left or right without changing its direction on the paper; does it along its whole length continue to point in the same map direction as at first?

12. Hold your pencil along the equator; in what direction does it point?

13. Slide it slowly up or down without changing its direction on the paper; does it continue along its whole length to point in the same direction as at the equator?

Advanced Questions. 14. Questions 1 to 9 call attention to inaccuracies which cannot altogether be avoided in representing a spherical surface in a plane. What are the inaccuracies?

15. Questions 10 to 13 call attention to inconveniences in the map. What are the inconveniences?



MERCATOR'S MAP OF THE EARTH

Purpose. To draw a map that shall represent the surface of nearly the whole earth, and in which the points of the compass do not shift in going across the paper. (See questions 10–13 in the exercise on the Globular Projection of the Western Hemisphere, p. 12.)

Material. Globe, ruler, hard, sharp pencil, drawing compasses.

On the accompanying double sheet of paper is a rectangle drawn for the frame of your map. Across this, $3\frac{1}{2}$ inches from the bottom (measure at both ends), draw a line 12 inches long, to represent the entire equator. Along the equator and also along the inner line at the top and at the bottom of the frame, make a dot every half inch. Through these dots draw lines to represent the meridians.

Questions. 1. How many meridian spaces are there in the map? Therefore, how many degrees apart are the meridians?

2. Reckoning the circumference of the earth as 25,000 miles, how many miles apart are the meridians at the equator?

3. Are the meridians on the globe the same number of miles apart at 10°, 20°, 30°, etc., from the equator?

Are they equidistant on your map?

Is, therefore, the scale at which the map is drawn at one latitude the same as that at which it is drawn at another latitude?

For this reason no scale is commonly given for a Mercator's map, except sometimes a scale for the equator.

4. Imagine a circular island 100 miles in diameter at the equator and another of the same size at 60° latitude. At 60° latitude the meridians in Mercator's map are "stretched" apart to double their normal distance. Into what shape, therefore, would the circle imagined at 60° on the earth be "stretched" on the map?

5. How could this figure, while keeping its double east-west size, be brought to the form of a circle again?

In order, then, to represent on the Mercator's map small bodies of land or water in their true shape, a band of 10° of latitude at 60° from the equator should occupy as much space as 20° along the equator.

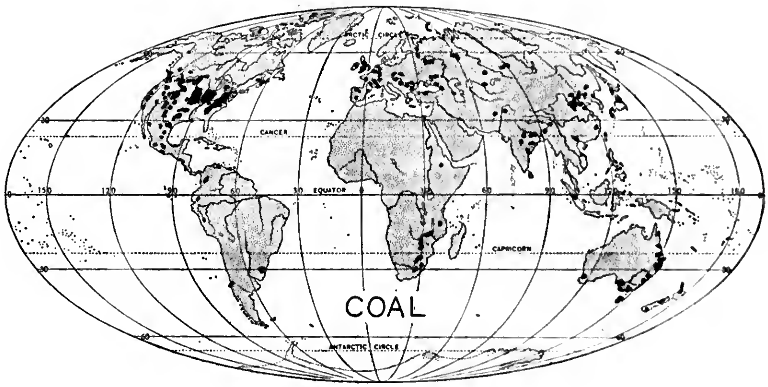
The east-west "stretching" between meridians has been computed for each 10°, and the space that would normally be occupied by 10° of latitude on this map ($\frac{1}{3}$ inch) has been multiplied by this number, that the north-south exaggerations might equal the east-west, and so the correct forms of small areas be maintained. Draw a line for 10° latitude $\frac{11}{32}$ inch from the equator, one each side; for 20° draw a line almost $\frac{3}{8}$ inch from the 10° line (almost $\frac{23}{32}$ inch from equator); for 30°, a very little more than $\frac{3}{8}$ inch from the 20° line ($1\frac{3}{32}$ inches from equator); for 40°, $\frac{7}{16}$ inch from the 30° line ($1\frac{17}{32}$ inches from equator); for 50°, $\frac{1}{2}$ inch from 40° ($2\frac{1}{32}$ inches from equator); for 60°, a little more than $\frac{5}{8}$ inch from 50° (a little more than $2\frac{21}{32}$ inches from equator); for 70°, one inch from 60° (a little more than $3\frac{21}{32}$ inches from equator); for 80°, a little more than $1\frac{7}{8}$ inches from 70° ($5\frac{9}{16}$ inches from equator).

6. Why not continue the map to the pole?

The Arctic Circle should be drawn not quite $\frac{1}{2}$ inch north of 60°, and the tropical circles less than $\frac{1}{8}$ inch from 20°.

Sketch in the outlines of North and South America, and Greenland, after having carefully located their prominent points, as in the Globular Projection.

7. On the globe, how does Greenland compare in size with South America? How do they compare on your map?



THE MOLLWEIDE PROJECTION

Advanced Questions. The Mollweide Projection is another means of representing the entire surface of the earth.

8. Which map, the Mollweide or the Mercator, would be more convenient for showing the directions of wind and of currents of water? Which would be more useful to navigators?

9. Which map would be better for showing comparative areas?

10. Although the Mollweide does not exaggerate size in any part, it has what drawbacks?

11. What part of the Mollweide has the greatest distortion of shape? What part has least?

LENGTH OF DAY AND NIGHT

Purpose. To find the number of hours the sun is (*a*) above the horizon, and (*b*) below the horizon at certain times and places.

Material. A 6-inch globe and a rubber band $\frac{9}{10}$ inch wide, to encircle the globe.

Place the globe on the desk before you, north pole tipped $23\frac{1}{2}°$ to the right. Raise it to the level of your eyes, which will represent the sun. This is the position the earth has relative to the sun March 21.

1. Imagine a thread from the center of the sun to the center of the earth. At what point does it pierce the earth's surface?

This is called the "vertical ray."

2. What angle does it make with the earth's surface?

3. With the earth's axis?

4. How much of the earth's surface is in the sunshine? How much in the darkness?

Rotate the globe toward the east (from your left to right).

5. What two places stay in the line dividing sunshine from darkness?

6. On which side of the globe does every city come from darkness into the sunshine (sunrise)?

7. On which side does every city go from sunshine into darkness (sunset)?

8. How far across the sunshine area has each city passed at its noon?

9. Where is every city at midnight?

Place the band around the globe so that the edge nearer the sun shall lie in the line dividing sunshine from shadow.

10. If the meridians on the globe are 15° apart, how much time does each space between meridians represent?

11. Each point on the equator passes through how many hours from sunrise to sunset?

12. From sunset to sunrise?

The space under the band has twilight.

13. Does the band cover the same number of hour spaces at all latitudes?

14. In what latitudes is twilight very short?

15. In what latitudes very long?

In the table given below fill out the March column for all the places given. (Twilight is included in night.)

LENGTHS OF DAY AND NIGHT

Place	Latitude	March 21		June 21		December 22	
		Day	Night	Day	Night	Day	Night
Mouth of Amazon River	0°						
Your own city							
Rio de Janeiro	23° S.						
North Cape	71° N.						

16. On what other day of the year will the sun be above the horizon and below the horizon the same number of hours as on March 21 ?

Remove the band from the globe. Keeping the axis pointing to the same spot in the heavens as in the March position, move the globe to your left one fourth of the way around your head. This is the June position.

17. Which polar region is now entirely in the sunshine?

18. Which entirely in the shadow ?

19. At what latitude does the vertical ray touch the surface?

20. What angle does the sun's ray make with the axis?

21. How many degrees past the north pole does the sunshine reach ?

22. How many degrees does it fall short of reaching the south pole?

Place the band around the globe in the June position so that the edge nearer the sun shall lie in the line dividing sunshine from shadow. Fill the June column in the table.

Remove the band. Keeping the axis pointing to the same spot in the heavens, revolve the globe further to the left, from the June position one half way round your head. The globe is now in the December position.

23. Which polar region is entirely in the sunshine?

24. Which in shadow?

25. At what latitude does the vertical ray strike the surface?

26. How many degrees past the south pole does the sunshine reach?

27. How many degrees does it fall short of reaching the north pole?

Place the band around the globe to represent the December position, and fill the December column in the table.

Fill the blanks in the following general statements, and cross out in each pair the word which is incorrect.

At the equator all days are —— hours long.

The higher the latitude, the *longer shorter* the summer day, and the *longer shorter* the winter day.

On March 21 and September 23 all places have *equal unequal* day and night of —— hours.

The lower the latitude, the *longer shorter* the twilight.

SUNRISE AND SUNSET GRAPHS

Purpose. To study and compare graphically the lengths of day and night through the year at different latitudes.

Copy the following general statement, using the correct word only of each pair and filling the blanks: — A place nearer the equator has a *longer shorter* day in winter and a *longer shorter* day in summer than a place farther from the equator. About ________ (date) the nights and days are equal and ____ (number) hours long.

Write the numbers of the twenty-four hours of the day (12, 1, 2, 3, etc.) along the binding border of a sheet of cross-section paper (end of this book), each number at the end of a heavy line, beginning and ending with midnight. At one end of the sheet write the names of the months on twelve consecutive heavy lines. From the table given below, choose the latitude nearest that of the place in which you live, and find the time of sunrise January first. On the January line of the cross-section paper make a dot in the place that indicates the given time of sunrise. Find the time of sunset for the same day and make a dot in the proper place on the January line. The space between the dots shows the length of day. From the table get the times of sunrise and sunset on the first day of February, and make dots on the February line in the proper places for these times. Do the same for each month. Draw a line connecting the sunrise dots and another connecting the sunset dots. The space between these lines represents day, the space outside of them, night.

Questions. 1. About what time of the year is the day longest? How many hours long?

2. About when is it shortest? How many hours?

3. At about what date does the sunrise graph cross the 6 A.M. line? When does the sunset graph cross the 6 P.M. line?

On the same paper draw sunrise and sunset graphs for St. Petersburg, — using a colored pencil or dash lines to distinguish from the graphs first drawn.

4. About what time of year is the day longest? How many hours long?

5. About when is it shortest? How many hours?

6. When does the sunrise graph cross the 6 A.M. line? When does the sunset graph cross the 6 P.M. line?

7. Which of the two places has the longer summer day? Which has the longer winter day?

8. On what date does the graph of one place cross that of the other; *i.e.* when is sunrise or sunset for the two places at the same hour?

Be sure each graph is labeled at the end with the latitude of the place it represents.

Advanced Questions. Draw the graphs for 82° N. (Fort Conger), continuing the lines till they meet at about noon in February and in October, and until they reach midnight.

The opening between the lines at midnight means continuous day. About how long is it? About how long is the continuous night (indicated on the noon hour)?

Draw as many other graphs as you have time for.

MEAN LOCAL TIME OF SUNRISE AND SUNSET. 1899

Place	Para 0°		Cancer 23½° N.		Chicago 42° N.		St. Petersburg 60° N.		Ft. Conger 82° N.		Cape Town 34° S.	
Sun	Rise	Set	Rise	Set	Rise	Set	Rise	Set	Rise	Set	Rise	Set
January 1	6:00	6:08	6:41	5:27	7:28	4:40	9:02	3:06			4:52	7:16
February 1 . . .	6:10	6:18	6:40	5:49	7:12	5:16	8:15	4:13			5:21	7:06
March 1	6:09	6:16	6:21	6:04	6:34	5:51	6:55	5:30	8:55	3:34	5:48	6:36
April 1	6:00	6:07	5:52	6:16	5:42	6:21	5:24	6:45	3:50	8:25	6:12	5:55
May 1	5:53	6:00	5:26	6:28	4:55	6:59	3:56	7:59			6:35	5:19
June 1	5:54	6:01	5:14	6:42	4:25	7:30	2:48	9:08			6:57	4:59
July 1	6:00	6:08	5:17	6:50	4:28	7:40	2:40	9:26			7:06	5:01
August 1 . . .	6:02	6:10	5:29	6:43	4:52	7:20	3:36	8:34			6:53	5:20
September 1 . . .	5:56	6:03	5:42	6:18	5:25	6:34	4:50	7:10	1:45	10:00	6:18	5:42
October 1 . . .	5:46	5:53	5:51	5:48	5:57	5:43	6:03	5:36	6:40	4:55	5:37	6:03
November 1 . . .	5:40	5:48	6:05	5:33	6:33	4:54	7:24	4:04			5:00	6:28
December 1 . . .	5:46	5:54	6:25	5:14	7:09	4:30	8:35	3:03			4:40	6:58

THE PATH OF THE SUN

Purpose. To see how the sun appears to move through the heavens during the day at different latitudes and seasons.

Material. A six-inch globe with pin holes along longitude 180° at the latitudes given below; a disk one inch in diameter with two diameters drawn at right angles and marked at the ends N., E., S., W., and through whose center a pin is thrust to its middle; a single bright light in a room otherwise darkened.

Prick no holes in the globe, but put the pin holding the disk into a hole already made at longitude 180°, latitude 0°. Be sure the N. is to the north. The pin represents you, the disk your horizontal plane. Turn your back to the light which is to represent the sun; hold before you in the light the globe, in the March 21st position, *i.e.* north pole tipped 23½° to the right. Have the disk on the dark side of the globe; rotate the globe slowly counterclockwise. When you (the pin) reach the sunrise line, the light will first fall on the surface of the disk and your shadow will appear.

1. In what direction does the shadow extend?

2. In what direction, then, is the rising sun?

3. As the globe slowly rotates observe the movement of your shadow. Where is it at noon?

4. Where, then, is the sun at noon?

5. What is the direction of the setting sun?

6. On what other date does the sun move through the heavens in the same path as on March 21?

Holding the globe in the same place change it to the June position, *i.e.* north pole tipped 23½° toward you. Beginning with the disk in the shadow, rotate as before.

7. Does the sun rise north, or south, of east?

8. At noon is the sun north, or south, of overhead (zenith)?

9. Does the sun set north, or south, of west?

Holding the globe in the same place, shift it to the September position, the north pole tipped to the left. Rotate as before.

10. What is the direction of the rising sun?

11. Of the sun at noon? Of the setting sun?

Shift the globe to the December position, north pole tipped 23½° from you.

12. Does the sun rise north, or south, of east?

13. At noon is the sun north, or south, of the zenith?

14. Does the sun set north, or south, of west?

In each column of the table below write the direction of the sun in 0° latitude.

DIRECTION OF SUN AT RISING, AT NOON, AT SETTING

Latitude	March 21			June 21			December 22		
	Rising	Noon	Setting	Rising	Noon	Setting	Rising	Noon	Setting
Equator									
Your city . . .									
23° S.									
71° N.									

Move the pin with the disk to the latitude of your own city. Find the directions of the sun morning, noon, and evening in March, June, and December, and fill blanks in the table.

Move the pin and disk again to latitude 23° S. Find the directions of the sun as before and write in the table.

Repeat the study for latitude 71° N.

15. At places far north from the equator does the sun rise in June more, or less, north of east than at the equator?

16. In December more, or less, south of east than at the equator?

17. If the sun rises north of east, where will it set? If it rises south of east, where will it set?

General statements of the directions of the rising and setting sun, etc., may be made, similar to the general statements at the end of the exercise on Length of Day and Night, p. 20.

In the recitation following this exercise, the pupil should be required to indicate, with a pointer moving steadily at arm's length, the path of the sun through the sky on the days and at the latitudes given.

STANDARD TIME

Purpose. To study the time belts commonly employed in the United States.

Questions. 1. How many hours is 75° W. longitude different in time from London? When it is noon at London, what time is it at this meridian?

On a blank United States map (p. 193) draw this line, 75° W., heavy with ink or colored pencil.

2. Name a large city lying near this longitude.

3. When it is noon at London, what time is it at 90° W.?

Draw this meridian as you did the 75th.

4. Name three large cities near it.

5. When it is noon at London, what is the hour at the 105th meridian west? Draw this meridian.

6. Name a large city near it.

7. When it is noon at London, what is the hour at the 120th meridian west? Draw this meridian.

8. Name a large city near it.

The meridians mentioned above are the centers of the four time belts of the United States.

9. How much does each differ from its neighbor in time?

Theoretically, the division lines between the time belts should be halfway between these meridians. Draw light lines to mark their positions, $67\frac{1}{2}$° W., $82\frac{1}{2}$° W., etc. At the north border write the names of the time belts; east of $67\frac{1}{2}$° W. is Atlantic Time (used in the eastern part of Canada and Newfoundland); then Eastern Time, Central Time, Mountain Time, Pacific Time.

Practically, the railroads regulate the time and make the hour changes to suit their convenience at the ends of railroad divisions. Draw heavy lines through the points named below, and you will have approximately the standard time boundaries as they are practically used.

Between Eastern and Atlantic Time — the eastern boundary of Maine.

Between Eastern and Central Time — from Port Arthur through Lake Superior and Lake Huron to Detroit, to Buffalo (keeping north of Lake Erie), to Erie, Pittsburg, Parkersburg, Asheville, Atlanta, Augusta, Savannah.

Between Central and Mountain Time — Qu'Appelle, Bismarck, North Platte, Dodge, El Paso.

Between Mountain and Pacific Time — Calgary, Boise, Reno, El Paso.

Advanced Questions. 10. Why is Mountain Time omitted on the Southern Pacific Railroad in Texas and New Mexico?

11. Why in Nevada does Mountain Time extend almost to the 120th meridian?

12. Why does the Central belt extend so far west of its theoretical boundary?

13. Why do southern Georgia and Florida have Central Time rather than Eastern?

THE PHASES OF THE MOON

Purpose. To study the changes in appearance which the moon undergoes during the month.

Material. A small globe.

Let some object at the front of the room represent the sun, your head the earth, the globe the moon. Holding the globe at arm's length, turn yourself slowly once around to the left; the top of your head represents the north pole; the globe's movement represents the course of the moon around the earth.

Hold the globe a little north or south (above or below) of the line from the earth to the sun; it is now new moon.

Questions. 1. About what fraction of the moon's surface is lighted by the sun? Can you, the earth, see the light part?

2. Imagine the earth rotating on its axis. At what time of day does the moon rise (*i.e.* appear in the east on the horizon)? When does it set?

What is its direction at noon? At midnight?

Move the globe through one fourth of its orbit — one week's time.

3. How much of the illuminated half do you see?

4. When does the moon rise? When set? What direction is it in the morning? In the evening?

Revolve the moon through another fourth of its orbit. It is now called "full."

5. How much of its illuminated half do you see?

6. When does it rise? When set? Where is it at noon? At midnight?

Revolve the moon through the third fourth of its orbit.

7. Make four sketches (name each) to show the form of the bright moon at each quarter; mark the east side E. and the west side W.

Advanced Questions. 8. At one end of a sheet of note paper write an S to represent the sun. One and one half inches from the other end, write E for the earth; to represent the moon's orbit, draw a circle, one inch radius, around E. Indicate the position of the moon at each quarter. Name all parts of the diagram.

9. During the first and fourth quarters the moon is crescent; during the second and third quarters it is gibbous. Sketch each form.

10. If you hold the moon firmly in your hand during its revolution, does it rotate on its axis? Do we ever see more than one side of the moon?

PRELIMINARY STUDY OF MINERALS

Purpose. To learn the appearance of minerals in granite.

Material. Labeled specimens of clear quartz, gray or pink feldspar, black mica, and hornblende, and a piece of coarse granite.

Questions. 1. Judging from color alone, how many different substances do you find in the piece of granite?

2. Are the different colors of the grains quite distinct, or do the colors blend into one another? Allowing for difference in size, are the grains as distinct as in the mineral specimens you have when held together in the hand?

3. Describe the grains that most closely resemble the quartz specimen by telling whether they are shiny, dull, smooth, rough, etc. What common substance do these grains resemble?

4. Describe in a similar way the grains that most closely resemble the specimen of feldspar.

5. Do you find any grains in the granite that closely resemble the mica or the hornblende? If so, how do you distinguish them?

6. Make a list of the minerals that appear to be in the granite.

THE STUDY OF MINERALS

Purpose. The mineral specimens used in the previous exercise, together with calcite, gypsum, rock salt, kaolin, and a few others, are among the most important minerals in the formation of rocks. These minerals may be more fully studied by using the following outline:—

1. *Name.* Give the name of the mineral.
2. *Color.* Give the color or colors of the mineral.
3. *Transparency.* Minerals are (*a*) transparent, when clear like window pane; (*b*) translucent, when a small amount of light gets through, as through a window shade; (*c*) opaque, when no light goes through. Hold your mineral toward a window and decide as to its transparency.
4. *Hardness.* Minerals and rocks are (*a*) very soft, if easily scratched with thumb nail; (*b*) soft, if easily scratched with steel rod; (*c*) hard, if scratched with difficulty with steel; (*d*) very hard, if they cannot be scratched with steel. Test your mineral in the above order and record its hardness.
5. *Acid Test.* Put a drop of hydrochloric acid on the mineral and watch the effect. If the mineral is affected, bubbles of gas will be formed. Give the result of your test.
6. *Porosity.* A dry mineral is porous, if a drop of water or acid sinks rapidly into it. It is compact, if the drop remains for some time on the surface. Test your mineral and tell whether it is porous or compact.
7. *Durability.* The durability of a mineral depends very largely upon its hardness, its resistance to acid, and its porosity. As you have already made these tests, tell why you think the mineral would make a weak or a durable part of a rock.

THE STUDY OF ROCKS

Purpose. The different rocks composing the crust of the earth are either igneous rocks or rocks derived from igneous rocks by the action of such forces as the weather, great heat and pressure, and chemical agencies. The following studies are intended to emphasize the important properties of the common rocks, such as: I. Igneous rocks (granite and gneiss), II. Calcite rocks (limestone and marble), III. Clay rocks (shale and slate), IV. Quartz rocks (sandstone and quartzite), V. Miscellaneous rocks.

I. **Granite and Gneiss.** Granite results from the slow cooling of lava under heavy pressure. Gneiss is composed of the same minerals as granite, but is coarsely banded, a structure probably due to a rearranging of the minerals in granitic rocks.

1. What is the general color of the granite? Of the gneiss?
2. How are the minerals arranged in the granite? In the gneiss?
3. Name and give the color of the different minerals found in each rock.
4. Tell the shape of the grains, whether rounded or angular.
5. Could the grains have been collected by running water and bound together as you see them here? Give a reason.
6. How does a drop of acid act when put upon each rock?
7. How hard is each rock as shown by steel-rod test?
8. Which rock do you think is better for buildings and monuments, and why?

II. **Limestone and Marble.** When granite rocks decay, certain minerals, especially feldspar, yield lime, which, uniting with carbon dioxide, produces calcite or limestone. Marble is a crystalline rock resulting from changes in beds of limestone.

1. What is the color of the limestone? Of the marble?
2. How do the two rocks compare in hardness? Are they soft or hard?
3. Describe the action of acid upon limestone; upon marble. If the action is very slow, the rock is probably dolomite (one containing some magnesium carbonate).
4. Do you find any fragments of shells in either rock? If so, describe them.
5. Which rock would make a better interior finish? Which is more extensively used for outside work? Why?
6. If the surface rocks of a region consist of masses of granite and limestone, which would weather the more rapidly and so form valleys? Which would form the ridges and hills? Give a reason for your answer.

III. **Shale and Slate.** Another product of the decomposition of feldspar and similar minerals is mud or clay (kaolin). This fine material is carried into the sea, and there by moderate heat and pressure may be made into shale. Greater heat and pressure will produce slate.

1. What is the color of the shale? Of the slate?
2. Which rock has the smoother and softer feel?
3. Can you scratch either rock with the thumb nail? Determine by other tests, if necessary, which is the harder rock.
4. Examine the rocks with the magnifier. Can you see the grains distinctly in either? Why?
5. How does a drop of acid act when put upon each rock?
6. Which rock do you think would be more easily affected by rain and frost? Why?
7. Why can slate be used for blackboards and roofing, and not shale?
8. If a level region consisting of granite, limestone, and shale is exposed for a long time to the weather, which of the rocks would probably form the ridges and which the valleys? Why?

IV. **Sandstone and Quartzite.** When granite decomposes, quartz alone remains unaltered. Grains of quartz are collected by running water and bound together by a cement into sandstone. The cement is probably carbonate of lime, if white or gray, and iron oxide, if yellow or brown. Quartzite, in which silica is the cement, has been formed by pressure, heat, and chemical changes in beds of sandstone.

1. What is the color of the sandstone? Of the quartzite?
2. From which can you loosen grains the more readily with the steel rod? Which, therefore, is the firmer rock?
3. Examine both rocks with the magnifier. In which can the grains be more easily seen? What is the reason?

4. How does a drop of acid act when put upon each rock? In what way does this test determine relative compactness?

5. From what you know about cements, which kind do you think holds the grains together in the sandstone?

6. Which rock would make a better building stone? Which is more commonly used? Why?

7. If masses of granite, limestone, shale, and sandstone compose the surface rock of a region, which of them would in time form valleys and which hills? Why?

V. Miscellaneous Rocks. If it is desirable to study other kinds of rocks, the following questions may be used: —

1. Give name and color of the rock.
2. Describe the structure, whether (*a*) fine or coarse, (*b*) porous, cellular, or compact, (*c*) uniform, banded, or stratified.
3. Has the rock a smooth or a gritty feel? A bright or a dull luster?
4. Is its weight light, medium, or heavy?
5. How hard is the rock?
6. How does a drop of acid act when put upon the rock?
7. What minerals can you find in the rock?
8. For what uses is the rock well adapted? Why?

Porosity of Rocks. In connection with the study of rocks the following test of their porosity may be made: —

Take samples of dry granite, sandstone, limestone, and shale of about equal size (as large as a walnut) and weigh each carefully. Put them into a dish of water, and after two or three days take them out, wipe off the surface water, and weigh them again. From these weighings determine the relative porosity.

Fill out a table like the following: —

Name of Rock	Dry Weight	Wet Weight	Increase	Percentage of Increase

COMPOSITION OF SOIL

Purpose. To study the composition of soil.

Material. A sample of moist soil, a hand magnifier, a glass plate, dilute hydrochloric acid, a closed vial containing ¾ inch of the soil and not quite filled with water, three shallow pans, some sand and some clay, and an apparatus, described below, for testing the porosity of soils.

Questions. 1. What is the general color of the soil?

2. Put a little of the soil on the glass plate and examine it with the magnifier.

(*a*) Do you find any pebbles or fragments of rock? If so, give their sizes, shapes, and kinds.

(*b*) Do you find any grains of sand? If so, give their colors and shapes.

(*c*) Do you find any rock waste finer than sand? If so, by what name is it generally known?

(*d*) Put a drop of acid upon the soil. What does the test show?

(*e*) Look for vegetable matter, such as roots, bits of leaves, bark, or stems. Describe what you find, and tell whether the amount is large or small.

(*f*) Do you find any fragments of shells? If so, describe them.

(*g*) If you find any seeds, describe their appearance. (The seeds are probably from weeds, and would grow under favorable conditions.)

(*h*) Describe any other substances you find in the soil.

3. Carefully examine the vial containing soil, and make a drawing of it. Label the different parts of the contents.

4. Gently shake the vial until all the soil is in suspension, then place it upon the table and observe what part settles first, what next, and so on, and what floats. Describe the order in which the various parts settle.

5. The apparatus for showing porosity of soil consists of three or more large test tubes with small holes in the bottom, stopped with cotton to prevent the soil from running through. These test tubes are fastened to a stand and nearly filled with different kinds of soil, one with clay, one with sand, one with soil under examination, etc. Pour water into the tubes and compare the number of drops that fall from each in two or three minutes. How do the soils compare with each other in porosity?

6. Will the soil under examination allow air and water to enter it readily? Why? Would it be called light, medium, or heavy?

Advanced Questions. 7. Name the different rocks that may have contributed to the formation of this soil.

8. Put a quantity of sand into one of the large pans, clay into another, and the soil under examination into a third. Wet all thoroughly and stir one half of each sample with a stick, leaving the other half undisturbed. Set them aside for a few days, and when they are fully dry, examine them to see whether the soils "cake" and how they are affected by working them when wet. Write a full description of this operation and the results.

IRON COMPOUNDS

Purpose. To study some of the important compounds of iron.

The principal ores from which iron is obtained are (1) Hematite (Fe_2O_3), (2) Magnetite (Fe_3O_4), and (3) Limonite ($2\ Fe_2O_3$, $3\ H_2O$). The first two contain about 70% of iron and the last about 60%.

Iron pyrites (FeS_2), "fools' gold," has a brass-yellow color with a metallic luster, and the crystals are often cubical. This mineral is of no value as a source of iron, as the sulphur cannot be entirely driven off. It is of importance, however, as a source of sulphuric acid and sulphate of iron.

A. Library Work. The pupils should consult works of reference, such as Census Reports, Geologies, and Commercial Geographies, to find:—

1. Location of large deposits of iron.
2. How the ore is mined, where it is marketed, and how it is smelted.
3. How cast iron, wrought iron, and steel are made.
4. The advantages of finding iron ore, coking coal, and limestone together, as in Alabama.
5. What three states lead in the manufacture of iron, and why?
6. The commercial importance of iron products.

B. Laboratory Work. The pupil should examine as many different kinds of iron ore as possible and for each kind determine the following properties:—

1. Color.
2. Luster.
3. Hardness.
4. Color of the streak made by rubbing the ore on rough paper.
5. Effect of acid.
6. Whether the weight is light, medium, or heavy.

COAL

Purpose. To study the characteristics of coal. The coal series comprises (1) Peat, (2) Lignite, (3) Bituminous coal, (4) Anthracite, (5) Graphite.

A. Library Work. The pupil should consult works of reference on coal (see under Iron Compounds) to learn: —

1. The origin of each kind of coal.
2. The kinds of rock associated with coal.
3. The location of large coal fields in the United States.
4. The three leading states engaged in the mining of coal.
5. The coking of coal and the use of coke.
6. The industrial use of each kind of coal.
7. The output of coal in the United States as compared with the rest of the world.

B. Laboratory Work. The pupil should examine specimens of as many kinds of coal as possible, also partly burned pieces of anthracite, to see the structure. Then a description of each coal should be written, giving: —

1. Color.
2. Luster.
3. Brittleness.
4. Fracture (irregular or shelly).
5. Hardness.
6. Structure features (make drawing).
7. Place small fragments of soft coal in a test tube fitted with a one-hole stopper through which is pushed a short glass tube drawn to a fine bore. Heat the test tube and light the gas driven out through the tube. Describe the various substances produced.

HARD AND SOFT WATER

Purpose. To determine whether water is hard or soft.

Material. Three test tubes, strong soap water, distilled or rain water, limewater, and the water to be tested.

1. Put distilled water into a test tube (half full), add two or three drops of the soap water, and shake vigorously. What collects at the top of the water? How much of it is there?

2. Repeat the operation, using limewater instead of distilled water, in another test tube. What collects at the top, and how much is there?

3. Again repeat the operation, using the water to be tested, in another test tube. What collects at the top, and how much is there?

4. Does the material gathered at the top of the test tube in the last trial more closely resemble that on the distilled water, or that on the limewater?

The result will indicate whether the water sample is soft or hard.

Another way to test the relative amounts of mineral matter in samples of water is to put a drop of each kind of water upon a clean piece of glass. When the drops have evaporated, hold the glass toward the light and compare the thickness of the deposits.

STALACTITES AND STALAGMITES

Purpose. To show how formations in caves are made.

Fill a large bottle with a saturated solution of alum or photographers' hypo. Put a siphon into the bottle and by means of a pinch cock or a glass tube drawn to a fine point, cause the drops to form very slowly — one every half minute — and allow them to fall upon two pieces of fine-mesh copper or brass gauze, supported one a few inches below the other. Examine this from time to time and note the growth of the deposits. Write below a full description of the experiment and make a drawing of the apparatus and deposits.

ALKALI PLAINS

Purpose. To show how arid plains become alkaline.

Material. A dish of sand and a saturated solution of alum or salt.

Put some dry sand into a dish and wet it well, but do not flood it, with the alum or salt solution. Stand the dish aside for a few days, and a layer of alum or salt will be found over the surface. After the experiment is completed, answer the following questions: —

1. How did the salt get to the surface?

2. Where do the alkaline salts come from that are found on the alkali plains?

3. How do they get to the surface?

4. Why are alkali plains found only where there is little rainfall?

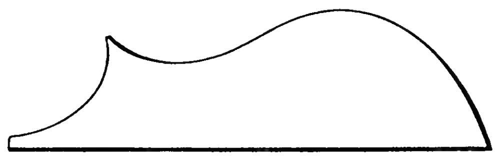
5. How will abundant irrigation make these alkali plains productive?

MODELING

Sand Modeling. Whether sand modeling is valuable or not in representing very large areas, it surely is a great help in the study of tracts so small that they can be represented on a scale of a mile or two to the inch. One particularly useful method of applying sand modeling is in representing processes. A river valley can be shown not simply as a finished product, but undergoing the development stages. And as the pupil digs out the valley, or sees it dug out, he does not overlook the fact that there is sediment to be disposed of. Processes like capture or the lateral shifting of divides, the understanding of which requires a clear conception of the third dimension, and which are therefore so difficult to explain by blackboard sketches, are easily demonstrated in the sand tray.

Sand modeling is very useful, also, as a test of the pupil's interpretation of a map. After the pupil has studied a map of the Appalachians or of the Grand Canyon, let him model a portion of the area five or six miles square, with very little vertical exaggeration. The first results will be a revelation to the teacher.

The sand tray should be of metal — aluminum, zinc, or galvanized iron, 16 by 24 inches or larger, with sides not more than two inches high. Common sand may be used, but fine molding sand from a foundry is better. The sand must be freed from lumps and the moisture evenly distributed by working through the fingers. The beginner usually gets the sand too moist; it should be stiff, just wet enough to stick well together. The method of manipulation is very important. If you try to press down the sand for valleys and pinch it up or heap it up for divides, you can hardly get good results. Most land surfaces are plains, high or low, more or less cut up by streams. Follow nature's method. Level off a heap of well-packed sand, then cut out the valleys. A simple little sand-modeling tool will be found of great convenience.



Sand Modeling Tool

It has a straight edge three or four inches long, for shaving off a level surface, and curves and angles for cutting valleys of different forms. In cutting the valley, scrape off thin shavings of sand — a deep stroke is likely to break the sand mass. For volcanic cones and other forms not developed from a plain, the sand may be heaped up by the fingers.

A good exercise is to model from memory, and correct with the map in hand. Only the most general features of a landscape should be shown, and the work should be rapid. After the first trial, half a recitation period is enough time for one exercise. Remember that sand is to be used to represent topography — the character of valleys and divides. Simple position can be shown with less trouble on the blackboard.

Permanent Relief Models. If it is desired to represent the details of a region accurately to scale, a more durable model should be made. By means of carbon paper, trace the lowest contour of the map on cardboard; cut the cardboard along the tracing, and glue the piece on a board. On another piece of cardboard trace the next higher contour, cut it out, and glue it on the first piece. Great care must be taken to get the new piece exactly in the proper place; one way to do this is to make pinholes at the points of high elevation, through the map and through each piece of cardboard while the contour is being traced on it. Continue till all the contours have been traced and the pieces mounted. With molding clay wet with glue, fill in the angles at the edges of the cardboard so that the surface shall slope naturally. Paint or shellac will make the model complete.

The work may be divided among the members of a class, each marking and cutting one contour. By choosing cardboard of a certain thickness, the vertical exaggeration can be made as desired. *E.g.*, if the map scale is one inch to the mile, and the contour interval 100 feet, cardboard of a thickness 50 sheets to the inch would give no vertical exaggeration.

To get duplicates of the model, first make a plaster mold; then in it you can make as many casts as you wish. To make the mold, the model must first be well coated with shellac. When this is thoroughly dry, surround the model with a rim higher than its highest point. Cover the model and inner surface of the rim with a light lubricating oil (sperm is good; do not use a drying oil), and pour in plaster of Paris, wet to an easy-flowing consistency. After twenty or thirty minutes the mold can be removed from the model, and any flaws touched up. After the mold is dry, give its inner surface

two or three coats of shellac. Oil it as you did the model, and pour in liquid plaster for the cast. If the heads of two or three small bolts are imbedded in the plaster while it is setting, the cast can be conveniently fastened to a board. Hair or some other binding fiber should be mixed with the plaster before wetting, that the cast may not fall to pieces if it should sometime be cracked.

A Wet Laboratory. A lead-topped table, several feet long, having raised edges, and supplied with running water, will lend considerable interest to the study of land forms.

One exercise consists in building up a mound two or three feet square of well-packed molding sand. Make the mound six to ten inches high, with nearly vertical sides and level top. Over the top scatter pieces of slate an inch or two across, and a few large pebbles. Cover an inch deep with sand and pack down hard, hammering in some small depressions an inch or two deep to serve as lake basins. Turn a *very* fine spray over the model in such a manner that one edge and a small part of the top are not affected, so as to remain for comparison. Build a dam across the outlet of the table so that the run-off will form a body of water three or more inches deep, in which deltas and fine offshore deposits will form. Ravines, head erosion, development and recession of waterfalls (positions marked by small stakes), disappearance of lakes, and differential erosion can be clearly shown. Before drawing off the large body of water, fan it into waves, and a clearly cut shore-line will be developed.

After the valleys are well formed, the effect of a sinking coast can be well shown by increasing the depth of the body of water. The effect of a rising coast, in producing a coastal plain with flat divides, can be shown by decreasing the depth of the water.

To develop water gaps and monadnocks, imbed some vertical layers of sun-baked modeling clay. A mountain fold may be made to rise across the stream by imbedding horizontally a short, narrow board, from the ends of which vertical wires extend up through the sand, so that by lifting the board a little at a time the overlying sand may be cautiously raised as the stream cuts across the ridge.

Another interesting result can be secured by laying two or more strings of tubing from the water faucet along the top of the modeling table, and building over them a plateau similar to the one described above. Do not use the spray, but adjust the ends of the tubing so that the water will emerge as springs on the plateau, and produce the canyon valleys characteristic of a rainless region.

Some pupils may increase the general interest by modeling a bit of landscape, such as a valley containing a stream with a waterfall, and dotting the hillsides with toy trees, houses, factory buildings, and coal mines, and developing a system of roads and railroads resulting from the topography.

FIRST EXERCISE WITH CONTOURS

Purpose. To familiarize pupils with the use and meaning of contours.

Material. A large board or table, a quantity of fine, moist sand, some blocks of wood one inch thick, and a pointer. (Note. If it is not convenient for each pupil to make this model, a few of them under the direction of the teacher may make a large one for the whole class.)

Directions. Fashion the moist sand into any desired hill-form with irregular slopes. Make a river valley on one side and a sharp ridge somewhere else. The base of the hill may be regarded as sea level, and is not represented by any other contour than the shore line. Place one of the blocks on the board or table beside the imaginary island, lay the pointer upon it, and with the end of the pointer touching the sand, move the block around the island. The pointer will trace a circular contour line in the sand one inch above sea level. Add another block and trace a second contour one inch above the former line.

Continue to add blocks and trace contours until the top of the island is reached.

Questions on the Model. 1. How many inch spaces are on the model? About how much of another space remains at the top?

2. If the hill were sliced through where the contours encircle it, what would be the thickness of each slice? This thickness is called the Contour Interval and is always the vertical distance between a contour and the one next to it.

3. As the contour interval is one inch, how high is the island? How high would the island be if the contour interval were ten feet? If 20 feet? If 100 feet?

4. Look directly down upon the island, as you are supposed to do when looking at any contour map.

(*a*) What is the general shape of the contours that represent a hilltop?

(*b*) Notice that the contours are not the same horizontal distance apart on all sides of the island. Where they appear very close together, is the slope of the hillside steep or gentle? What is the character of the slope where they are farther apart?

(*c*) Where the contours cross the river valley, do they bend up stream or down stream?

(*d*) How do the contours bend where crossing the ridge?

5. Make a drawing of the island as nearly the shape of the base as possible and about four inches across. Draw lines representing the contours each within others as seen from above. Draw a line for the river. Make the sea-level contour and the fifth and tenth contours heavier than the others (this is for convenience in counting) and mark each line with the proper height above sea level if the contour interval represents 100 feet.

6. Make the following statements read correctly: —

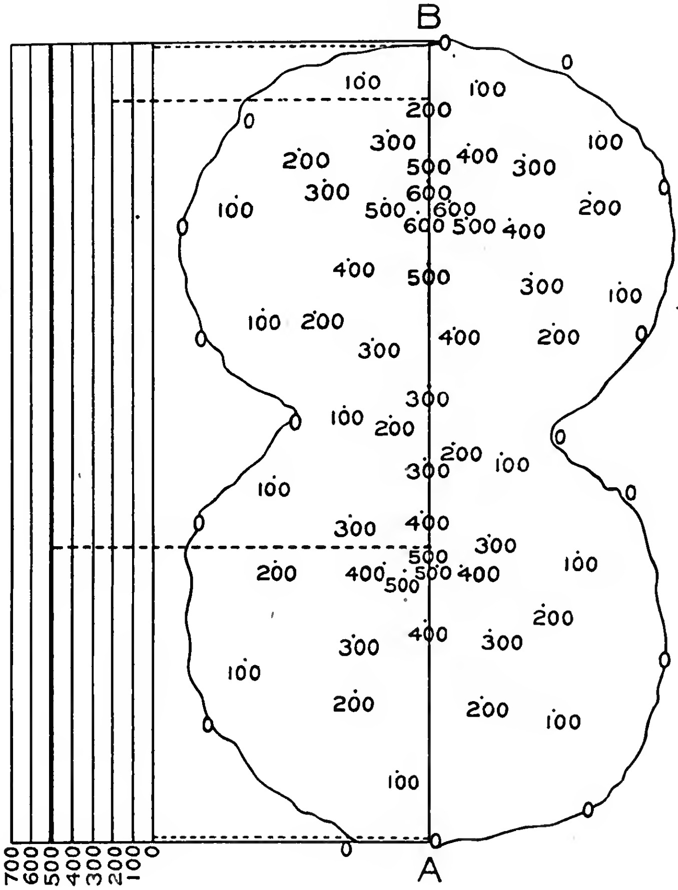
(*a*) Hilltops are represented by *straight-line closed-curve* contours.

(*b*) Where crossing a river valley, the contours bend *up down* stream.

(*c*) Where the contours are close together, the slope is *steep gentle*, and where they are far apart, the slope is ________.

SECOND EXERCISE WITH CONTOURS

Purpose. To construct a contour map from numbers placed on a chart.



Directions. The numbers on the chart are altitudes in feet, and represent the position of contour lines. These lines show the relief of an island in the ocean. Draw a curved line through the dots marked 100, another through the dots marked 200, and so on. No line should touch or cross another one.

Questions. 1. What is the general shape of the island? If one inch on the map represents a mile, how long is the island from south to north (line *AB*)?

2. Which end of the island, the north or the south, has the steeper slope? How can you tell?

3. How many hilltops on the island? How many miles apart are they? How many feet above the sea is each?

4. Draw lines representing the locations of two rivers on the map. Label one river *C* and the other *D*. How many miles long is each river? How high above sea level is the source of each river? How many feet of descent does each river have? What, therefore, is the average descent or grade per mile of each?

Profile along Line *AB*. Draw dotted lines from the points where each contour crosses line *AB* to that line in the rulings on the side of the map which has the same value as the contour. Make the dotted lines parallel with those already drawn as guides. Connect the ends of the dotted lines within the rulings, and the resulting line is the required profile, which shows how the western half of the island would look from the side, if the island were cut through vertically along the line *AB*, and the eastern half removed.

ILLINOIS. LA SALLE SHEET

Purpose. To study the earlier stages of valley development.

Description of the Region. The valleys selected for this study have been cut in the glacial drift and underlying rock of north-central Illinois.

Location and Extent. 1. To what geographic district does this region belong? (See map of Geographic Districts, p. 8.) On what scale of miles is the sheet drawn?

Relief and Drainage. 2. What contour interval is used here? To what drainage system does this region belong?

A. *A Study of a Small Gorge or Ravine.* Find the small gorge, south of the Illinois River, about $\frac{3}{4}$ of a mile west of the Vermilion River.

3. Are the contours that show this gorge close together or well spread apart? Do the sides have a steep or a gentle slope? Is the bottom of this gorge broad or narrow? How can you tell?

4. Does the gorge become deeper or shallower as one goes from the mouth to the source? How shown? Does the top of the gorge become broader or narrower as one goes in the same direction?

5. Count the contours that cross the bottom of the gorge and tell how many feet higher the head is than the mouth. How long is the gorge? What is the grade per mile?

6. Does this gorge have any tributaries? Does the sheet show many or few such gorges as this?

7. Make a sea-level profile on cross-ruled paper across this gorge where the 500-foot contour crosses it, and extend the profile to the road on each side; use the standard scale, *i.e.*, with the horizontal scale same as in the topographic sheet, and the vertical scale 1 cm. = 100 feet. This standard scale exaggerates vertical distances about twenty times their true proportion. Beginning on west side where the road turns, and going east, use following contours: 620, 610, 500, 610, 620, 620, road.

B. *A Study of a Young River Valley.* Notice the little Vermilion River that flows from the north into the Illinois at La Salle.

8. Are the contours along the river close together or widely separated? Does this show steep or gentle valley sides? Is the bottom of the valley broad or narrow, and how can you tell?

9. About $3\frac{1}{2}$ miles up this river from its mouth the 480-foot contour makes a loop across it. Find this place and give the depth of the valley here and the width at the top.

10. The contours along here cross the valley about a mile apart; what is the grade per mile? How does this grade compare with that of the gorge just studied?

11. Make a sea-level profile across this valley (crossing the river at right angles) where the 480-foot contour crosses it, using the standard scale. Put this beside the gorge profile on same sea-level line. Beginning on the west use the following contours: 620, 620, 610, 600, 480, 640, 640.

C. *A Study of a Broad River Valley.* The size of the Illinois River valley is largely due to the great volume of water that flowed out from Lake Chicago, the glacial enlargement of Lake Michigan.

12. Are the contours that represent the valley sides close together or well spread apart? What, therefore, is the character of the slope? Is the bottom of the valley (the flood plain) wide or narrow? How wide is the flood plain opposite La Salle? How do the contour lines show that the flood plain is comparatively level? Does the river have a direct or a meandering course along its flood plain? How many contours are represented as crossing the river on this sheet? How does the grade compare with that of the Little Vermilion?

13. Find a contour that best represents the altitude of the flood plain. What is it? Find a contour that best represents the altitude of the top of the bluff opposite La Salle. What is it? How deep, then, is the valley?

14. Make a sea-level profile across the valley a little east of the mouth of the Vermilion River, and extend it a half mile or more on each side, using standard scale. Make use of only those contours that show change in slope. Put this profile beside the others.

15. **Culture.** In which of the three valleys studied have wagon roads been constructed? Railroads? Canals? Why cannot these means of transportation be as easily constructed in the other valleys?

16. **Advanced Questions.** State two or three characteristics that you have noted which show that the valley of the Illinois River is farther developed than that of the Little Vermilion.

17. Do you find a river on the sheet that seems to represent a stage of development between the Illinois and the Little Vermilion? If so, what is it and why do you so regard it?

DRAINAGE AREAS

Purpose. To map and to study the drainage of the United States.

On a map of the United States showing the rivers (near end of this book — just before the cross-section paper), draw lines to show the principal drainage areas according to the following suggestions: —

I. Atlantic Drainage (not including the St. Lawrence). Begin at the north boundary of Maine and draw a line along the divide that separates the streams flowing into the ocean from those flowing into the St. Lawrence. In west-central New York, the divide turns southward, separating the head waters of the Ohio from the Susquehanna, thence along the Appalachian Mountains, through Florida to the southern end. Label the area east of the divide "Atlantic Drainage."

II. Gulf Drainage (not including the Mississippi). From the place where the previous divide enters Georgia, draw a line westward and then southward to the Gulf, which will separate the Tennessee River from the streams that flow into the Gulf east of the Mississippi. Then begin west of the Mississippi River and draw a line around all the streams that flow into the Gulf, including the Rio Grande. Label these two areas "Gulf Drainage."

III. Pacific Drainage (not including the Columbia River). Begin just below mouth of the Columbia River; draw a line southward along crest of the Sierra Nevada, and down to the south boundary of California. Label.

IV. St. Lawrence Drainage. From place where the Atlantic Drainage divide turns southward in New York, draw line westward south of Lake Erie, around end of Lake Michigan, and northward around end of Lake Superior. Label.

V. Mississippi Drainage Basin. From point where divide turns eastward around Lake Superior draw line westward around head of Mississippi River, southward around the head of the Red River of the North, north and west around head of the Missouri River, southward along crest of Rocky Mountains to line inclosing Gulf Drainage. Label.

VI. Colorado River Basin. From point where the divide crosses meridian 110° in Wyoming, draw a line close along the western side of Colorado River to the Gulf of California. Also, from point where the Rio Grande divide passes into Mexico, draw a line westward to the mouth of the Colorado. Label.

VII. Columbia River Basin. Draw a line from the Pacific divide in Oregon to the Colorado River divide, crossing northeastern Nevada, northwestern Utah, and southeastern Idaho. Also another line from the northwestern corner of Mississippi divide northwestward to Cascade Mountains, south along these mountains to central Washington, then southwestward to the ocean. Label.

VIII. Great Basin Drainage. In southern California connect the Pacific divide with Colorado River divide. Label.

IX. Hudson Bay Drainage. The region immediately north of the St. Lawrence and Mississippi river basins drains into Hudson Bay. Label.

Color all bodies of water blue, and the drainage areas different shades of red, orange, or yellow.

Questions. 1. Which of the drainage areas includes the largest part of the United States? Which the smallest?

2. Which has no outlet to the ocean? Is the rainfall of this basin heavy or light?

3. Which area occupies the central part of the United States? Name four important rivers belonging to this area.

4. What and where is the divide that separates the water flowing eastward into the Atlantic and the Gulf from that flowing westward into the Pacific?

5. About what fractional part of the United States drains toward the Atlantic and the Gulf, and what part toward the Pacific?

6. Why is the St. Lawrence basin better for commerce than the Mississippi River basin?

7. In what area do you live, and for what is it especially valuable?

THE MISSISSIPPI RIVER

Purpose. To study the alluvial valley of the Mississippi River from St. Paul to the Gulf of Mexico.

Material. Two maps, four sheets each, published by the Mississippi River Commission, St. Louis.

(*a*) Map of the alluvial valley of the upper Mississippi River.

(*b*) Map of the alluvial valley of the Mississippi River from the head of St. Francis Basin to the Gulf of Mexico.

Questions. **A.** *The Upper Valley.* 1. Give a common width of the flood plain (tinted area) between Cairo and St. Paul.

2. Most of the upper valley is preglacial. Give the locations of the two narrow stretches which the river has cut since the glacial period. They have a swift current and rocky bottom, the only obstructions to navigation between St. Paul and the Gulf.

3. Is the general course of the upper valley straight, regularly curved, or irregular?

4. Name two places at which the river meanders sufficiently to erode the sides of the valley.

5. How do the courses of the small streams in the flood plain compare with the courses of the same streams in the upland?

6. Name several cities located on the flood plain, and several on the bluffs bordering the flood plain.

B. *The Lower Valley.* 7. Give the maximum and the minimum width of the flood plain south of Cairo.

8. Give the straight-line distance from Cairo to the mouth of the Mississippi River, and also the river distance (see figures near the mouth). Explain the difference.

9. Compare the number of small streams in the lower flood plain with the number of those in the adjoining uplands, and explain the difference.

10. How do the meanders and cut-off lakes of the small streams compare in size with those of the Mississippi River?

11. What becomes of the water of the small streams that rise near the bank of the Mississippi between Memphis and Vicksburg, and flow away from it? Does the direction of their flow indicate that the banks of the Mississippi in this region are higher or lower than the general level of the flood plain?

12. How many miles wide is the delta from North Pass to Southwest Pass?

13. How many miles is New Orleans from the mouth of the Mississippi?

14. Name the cities that are built on the flood plain of the lower Mississippi, and those that are on the bluffs overlooking the flood plain. Why should these cities be at these particular places on the bluffs?

15. At what distance from the mouth of the Mississippi does its first distributary (the Atchafalaya) branch off?

16. Make a sketch map of the lower delta ("goose foot").

MINNESOTA. ST. PAUL SHEET

Purpose. To study the gorge and the terraces of the Mississippi River near St. Paul.

Description of the Region. The region represented by this sheet is in eastern Minnesota. The surface was considerably modified by the ice and water of the glacial period. Beneath a layer of glacial drift is the durable Trenton limestone, and below this is the soft St. Peters sandstone.

Location and Extent. 1. Between what meridians does this region lie? Between what parallels? How wide is the sheet in degrees? How long? To what geographic district does it belong? (See map of Geographic Districts, p. 8.)

2. What is the exact scale of miles? What is the approximate equivalent? How many miles wide is the region shown on the sheet?

Relief and Drainage. 3. What is the contour interval? To what large drainage system does this region belong?

A. *The Gorge* of the Mississippi River extends from Pike Island to the Falls of St. Anthony, just at the edge of the sheet (the Falls are not named on the sheet).

4. In what direction does the river flow along this part of its course? How long is the gorge? How wide at the top and how deep is it where the wagon road crosses near its mouth at Fort Snelling?

5. What is the name of the largest tributary to the gorge from the west? What falls are in this stream? How far up the stream have the falls already receded? How high are they as shown by the contours?

B. *The Terraces* were formed by the river cutting into its former flood plain.

6. In a general way how does the valley of the Mississippi below Pike Island compare in width and depth with that of the Minnesota? This broad valley was made during the glacial period, and since that time these rivers have been forming a new flood plain within the old one, leaving terraces in some places.

7. Find the terrace on the north side of the Mississippi between the mouth of the gorge and St. Paul. How wide is this terrace near St. Paul? How high above the newer flood plain is it? What part of this terrace at St. Paul is covered with buildings? Do you consider these buildings safe from floods, and why? Are those on the newer flood plain safe, and why?

Culture. 8. Can river boats go very far above St. Paul? Why? Give a reason, then, for the location of St. Paul.

Minneapolis, about ten miles farther up, has extensive manufacturing industries. From what source can factories there derive power? Why are these two cities so close together?

Advanced Questions. 9. Give a reason why factories are not built around Minnehaha Falls.

10. Give as many reasons as you can for believing the portion of the Mississippi above Pike Island younger than the portion below.

11. Give reasons for believing the valley of the Minnesota River as old as that of the Mississippi below their junction.

12. Make a sea-level profile across the Mississippi from "S. Base" on parallel 44° 55′ southward to Pilot Knob, using standard scale.

IOWA–ILLINOIS. SAVANNA SHEET

Purpose. To study a typical portion of the Mississippi valley and adjacent upland along the middle course of the river.

Description of the Region. This region lies in about the same latitude as Chicago. Although it was not covered by the ice sheet of the glacial period, yet the water from the melting of the ice front overflowed a large part of this region and deposited a thick layer of fine silt. The Mississippi occupies a broad, well-defined valley, which is characteristic of the river from St. Paul to near the mouth of the Ohio River.

Location and Extent. 1. Where is this region located? To what geographic district does it belong?

2. What is the approximate scale of miles? How wide is the region represented on this sheet?

Relief and Drainage. 3. What is the contour interval? Are the contours in general straight or crooked on the sheet, and does this show smooth or rough slopes?

4. Notice the flood plain of the Mississippi. How can you tell where the sides of the flood plain are? How wide is the flood plain at the southern end of the sheet? at its narrowest place above Savanna?

5. Do you find many or few contours on the flood plain, and what kind of surface does this show the flood plain to have? Do the contours follow closely along each side of the river, thus showing that the river is cutting a new valley in the floor of the old flood plain as it has done at St. Paul?

6. The river has a braided channel here, and the inclosed sandy islands show that the river has received more sediment than it can immediately move along. Do you find contours on any of these islands? What rise of water above that at time of survey would cover them?

7. The altitude of the top of the bluff is about 840 feet. What is the altitude of the flood plain, and how deep, then, is the river valley here?

8. What two tributaries of the Mississippi drain most of the upland region on the eastern side? How have they changed the former small relief of this region? Do you call the drainage of these two tributary basins complete or incomplete, and why?

9. With the blunt end of your pencil follow the divide between Plum River and Rush Creek from Savanna to the upper end of the sheet. Do any streams cross it? Do you think this divide is a narrow ridge or a broad strip, and why do you think so?

Culture. 10. Which of the two towns, Sabula or Savanna, is in more danger of floods, and why? What railroad crosses the Mississippi here?

11. Have the wagon roads been laid out on the rectangular plan, and why? Do the wagon roads as a rule follow divides or stream valleys?

12. What is the annual rainfall of this region? (See p. 8.) Is it sufficient to keep the small streams running the whole year? Look for intermittent streams, shown by broken blue lines. Is the rainfall sufficient for general farming purposes?

Advanced Questions. 13. Where is the line that marks the boundary between Illinois and Iowa, and what would naturally change it from time to time?

14. What evidence do you find to show that the Mississippi once had its channel on the east side of its flood plain below Savanna?

15. Make a sea-level profile across the Mississippi at a convenient place above Savanna, to the 800-foot contour on each side, using standard scale.

LOUISIANA. DONALDSONVILLE SHEET

Purpose. To study the swamp flood plain and levees along the lower course of the Mississippi River.

Description of the Region. An arm of the Gulf of Mexico once extended far north of this region somewhat like the Chesapeake Bay at present. This arm or bay has been nearly filled with river sediment, and the mouth of the Mississippi is now more than 180 miles below Donaldsonville. The dry land or natural levees on each side of the river have been made by the more rapid deposits here at the time of floods. Close along the river artificial banks have been built on top of the natural levees, thus keeping the water within its channel except at times of unusual floods, when the levees are washed away (see Nita Crevasse). Bayou Lafourche at Donaldsonville is one of the principal delta distributaries.

Location and Extent. 1. In what part of Louisiana is this region located? To what geographic district does it belong?

2. Give the approximate scale of miles. How does the width of this sheet compare with the St. Paul sheet in degrees and in miles? Explain any difference you may find.

Relief and Drainage 3. What is the contour interval, and does this suggest a region of little or great relief? What relief is indicated, also, by the small number of contour lines and by the extensive swamps?

A. *The Swamp Flood Plain.* 4. What is the altitude of the lowest contour on the northeastern side of the Mississippi? On the southwestern side? Is a large or a small part of these swamps below this contour level? Are the contours on these swamps close together or far apart, and what does this show as to the slope? Are there many or few streams in the swamps? Do you consider these swamps well drained?

B. *The Levees.* 5. What is the altitude of the lowest contour anywhere on the levees? Is this contour near the river or near the swamp? What is the value of the highest contour on the levee, and where is it found? Does the levee slope toward or away from the river? Where do you find two contour lines very close together? Where, then, is the slope the greatest? Do the small streams flow toward or away from the Mississippi?

6. The outbreak at Nita Crevasse occurred in 1890. Note its location, and tell why an outbreak is more liable to occur there than on the opposite side of the river. Where did the outflowing water deposit its sediment, and how has this deposit affected the width of the levee?

Culture. 7. Only what portion of this region is suitable for farming? What is the annual rainfall of this region? (See p. 8.) Will this amount run off quickly where the slope is so gentle? Of what use, therefore, are the ditches (the straight blue lines), and where do they carry the water?

8. Where are the two main wagon roads located? Why is not the common rectangular plan of roads followed here?

9. Make a sea-level profile across the levees and river near the stations of Winchester and Whitehall, beginning and ending with the 5-foot contour. Make the river channel 100 feet deep and containing 90 feet of water. Use standard scale.

Advanced Questions. 10. The principal crops of this region are sugar, cotton, and rice; by what two ways may they be sent to market? Which way is the quicker? Which way is probably the cheaper, and why?

11. Make a sketch of the river from Donaldsonville to College Point and mark the position of the swiftest part of the current by a broken line. At how many places is the river liable to break through its banks at flood time, and why? At what bends do you find evidences of crevasses similar to the Nita Crevasse?

MISSISSIPPI RIVER SHEET NO. 14

NOTE. These sheets are prepared by the Mississippi River Commission, St. Louis, Mo., and deal with the commercial importance of the river. Scale: 1 in. = 1 mi. If sheet No. 14 cannot be obtained, sheet No. 18 may be substituted by making a few changes in the questions.

Purpose. To study river conditions that attend flood-plain meanders.

Description of the Region. The region represented on this sheet is about midway between the mouth of the Ohio and the Gulf, and fairly represents a large part of the lower course of the Mississippi. The banks of the river consist of unconsolidated sand and silt, which are easily cut away by the current.

Questions. 1. Between what two states does this part of the Mississippi flow?

2. The numbers in the middle of the stream are river distances in miles below the mouth of the Ohio at Cairo, Ill. How far below the mouth of the Ohio is Ashbrook Point at Rowdy Bend? Sunnyside Landing?

3. Find Jones's Landing, and tell how many miles a boat must sail to go from there to Sunnyside Landing. How far does a boat sail in going from Jones's Landing to Upper Leland Landing, and how many miles would be saved if the river were cut through from one to the other?

4. At Rowdy Bend does the current line (a dotted black line) go on the outside or the inside of the middle of the channel? On which side, then, is the current the swifter? On which side is the river cutting away its bank?

5. On which side of Rowdy Bend has the sand bar (fine black dotted area) been formed? Does this represent a cutting or a filling? Does this operation and that in your answer to question 4 tend to increase or decrease the size of the meander?

6. Examine the other bends on the sheet and tell how they compare with Rowdy Bend in (1) location of current line and (2) cutting and filling.

7. Are these changes in the course of the river of sufficient importance to navigation to make new surveys necessary? Why more necessary in the Mississippi than in the Amazon or Congo?

8. Read the note printed in red on the side of the map. When was the first survey for the map made, and how shown on the map? How long afterwards was the river here again surveyed, and how is the position of the new channel shown?

9. Note the location of the red bank line on the east side of Georgetown Bend. How wide a strip of land was cut away at this bend? How long did it take the river to do this cutting? How wide a strip is yet to be cut away before the river will go across the neck, thus forming a cut-off? At the same rate as the previous cutting, when would this cut-off occur?

10. At which of the bends has the outer bank of the river been cut back the farthest? How far? What danger threatens the plantations located on the outside of these bends? How has Greenville been affected by the meanderings of the river?

11. Find the oxbow lakes Chicot and Lee. Tell how they were formed.

Advanced Questions. 12. Explain why no steamboat landings are on the inside of the bend. Make an ideal section across the river at Rowdy Bend, showing the relative depth of water from bank to bank.

13. Do you think another survey should soon be made? Why?

14. How would straightening the course of the river affect its velocity, and what effect would this have upon the prevention of floods and the amount of work the river could do?

Make longitudinal profiles of the Mississippi River and the Missouri River on a horizontal scale of 1 cm. = 100 mi., and a vertical scale of 1 cm. = 1000 ft.

MISSISSIPPI RIVER | MISSOURI RIVER

Stations	Distance from Mouth	Altitude	Stations	Distance from Mouth	Altitude
Mouth	0 miles	0 feet	Mouth	0 miles	395 feet
Ohio River	1100 miles	270 feet	Bismarck	1240 miles	1620 feet
Minnesota River	1940 miles	690 feet	Ft. Benton	2075 miles	2170 feet
Minneapolis	1950 miles	795 feet	Great Falls	2100 miles	3300 feet
Lake Itasca	2300 miles	1460 feet	Three Forks	2340 miles	4000 feet

CALIFORNIA. CUCAMONGA SHEET

Purpose. To study alluvial cones.

Description of the Region. The region represented by this sheet is in southern California and shows a portion of the southern slopes and outwashings of the San Bernardino Mountains.

Questions. 1. What part of the sheet shows the San Bernardino Mountains? The plain?

2. Do the contours show that the mountains have been little or much worn by streams? How shown? What do the contours show to be the general character of the surface of the plain?

3. Where does the grade of the streams that come down from the mountains change from steep to gentle? Where, therefore, do they begin to deposit their load of rock waste?

What is this deposit called?

4. In what general direction do the contours on the plain extend? Where they pass the mouth of Deer and San Antonio canyons, do they loop or bend toward, or away from, the mountains?

What does this indicate?

5. How do the contours show that these deposits are highest in the middle, or cone-shaped?

Where are the cones the broadest? Where narrowest?

6. What becomes of these mountain streams when they reach the apex of the cone? Therefore, of what material are the cones composed?

What is the probable origin of the streams that begin between the towns of Pomona and Ontario, and flow southward?

7. How do the dry divided channels of the streams across the cones show the distribution of the sediment? Add a sketch to your description.

8. Considering towns, wagon roads, etc., how does the population of a strip close to the base of the mountains compare with one a few miles away? Give a reason for this.

ILLINOIS. OTTAWA SHEET

Purpose. To study a region of immature surface drainage.

Description of the Region. This region lies in the north-central part of the state along the Illinois River. The ground moraine of the ice sheet was spread very evenly over the surface, and the relief that has developed since the glacial period has been largely due to the work of streams.

Location and Extent. 1. On which side of the Illinois River is the largest area that contains very few contours? What direction is this from the town of Ottawa? To what geographic district does this region belong?

2. What is the scale of miles of the sheet? How many miles north from the Illinois River valley does the level prairie extend? How far west from the Fox River valley? Then about how many square miles in this immature drainage region?

Relief and Drainage. 3. What is the contour interval, and does this interval suggest little or much relief? What is the meaning of the three closed-curve contours on this prairie? Judging from the size of the area encircled by each of these contours, do you think that the higher parts of the prairie are very conspicuous, and why do you think so? Do you think that the lower places between these elevations are 10 feet below the heavy contours, and why?

4. The water that drains off from this prairie reaches what stream on the south? The east? The north? The west? What is the difference in altitude between the central part of this prairie and the Illinois River? The Fox River about 2¼ miles above the town of Dayton? Buck Creek at a point about ½ mile above the word "Buck"? Pecumsaugan Creek, where it turns abruptly westward?

5. Along which of the above streams, those with deep valleys or those with shallow ones, has the margin of this prairie been most roughened by ravines and gorges? Along which streams will the process of roughening the surface of the prairie proceed most rapidly, and why? As the drainage becomes more mature, how will the relief of this prairie change?

Culture. 6. To what occupation is this prairie well adapted? Find the annual rainfall here, and tell whether it is sufficient for farming. Is the percentage of run-off here large or small, and how can you tell?

7. In what directions do the wagon roads on the prairie extend? How far can one travel in a north-south road without going up hill or down more than 10 feet? How far on an east-west road? Do you think the roads here are level or hilly, and why?

8. What near-by market do the farmers have for their surplus produce? When they have more than enough to supply this market, how may they send it farther?

Advanced Questions. 9. If this prairie has immature drainage, explain the absence of lakes and swamps.

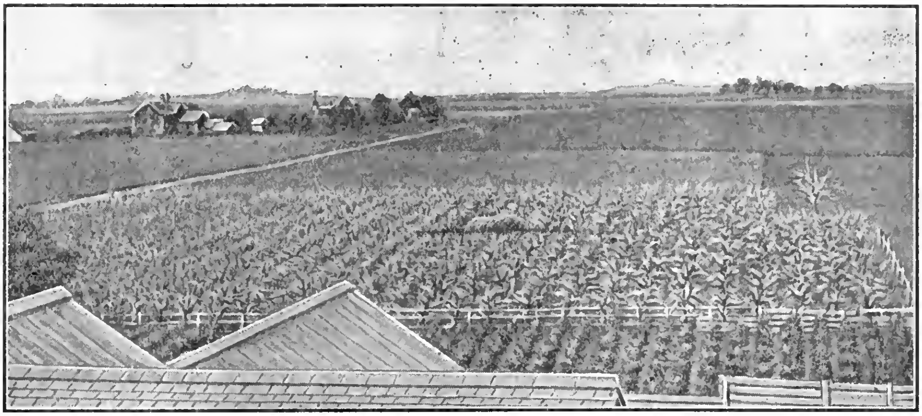
10. Has the region south of the Illinois River valley a greater or a less relief than the prairie north of the valley? Give a probable reason.

11. In what way does the work of rivers affect the relief of an elevated smooth region?

12. Make a north-south sea-level profile along the township line on the east side of the townships of Utica and Waltham, beginning at the Illinois and Michigan Canal and going as far as the cross-section paper will permit. Use standard scale.

PICTURE SUPPLEMENT — OTTAWA

Find on the map the location of each of the places shown in the following pictures.

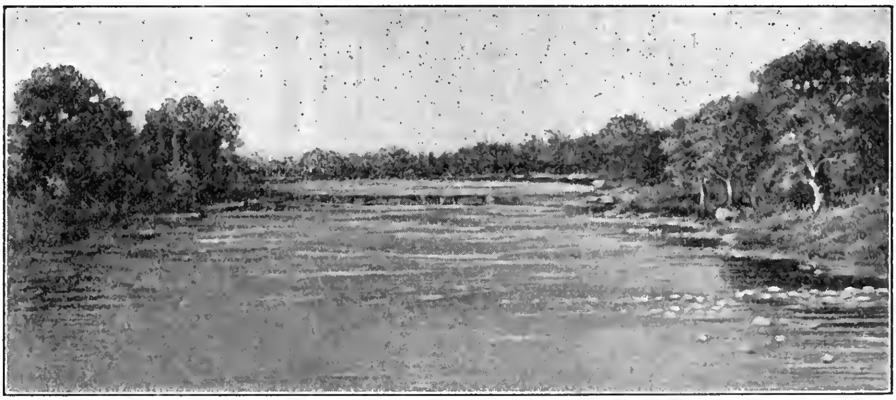


A. Looking north across the prairie, from the top of a windmill tower two thirds of a mile west of Dayton. The field showing obscurely at the right of the barn roofs is asparagus — grown for the Chicago market; beyond it is a cornfield with a rotting straw stack in the middle.

1. Describe the general appearance of the surface of the land.

2. Why do some farmers here need to spend hundreds of dollars in tile-draining their land?

3. Describe the farm buildings and surroundings at the left of the center of the picture.



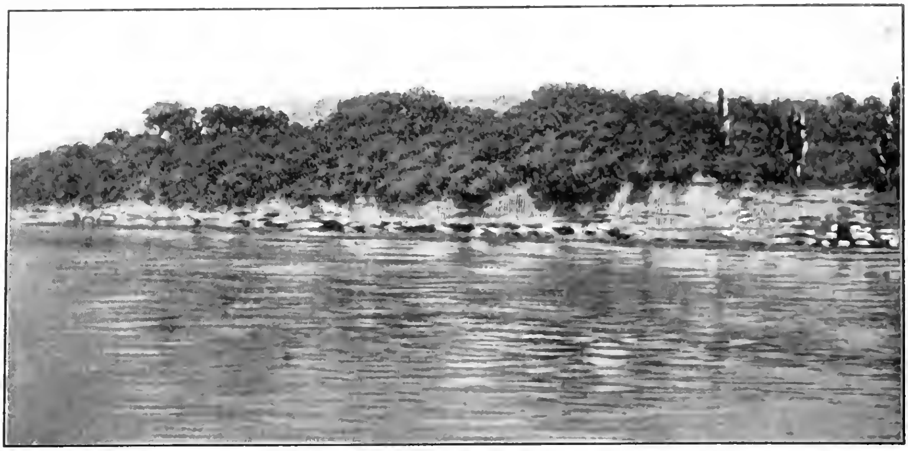
B. Looking north from the bridge at Dayton. The Fox River and banks only can be seen ; the valley sides are at the left and the right, outside the picture. The remnants of a dam appear some distance up stream. On the map observe the canal into which the water was turned by the dam.

4. What vegetation covers the banks of the river?

5. What material composes the bed of the stream?

Does this indicate a swift or a slow stream?

6. As far as you can see up stream, does the water seem smooth or rough? Does this mean steep or gentle slope?



C. The east bank of the Fox River, below Dayton bridge, but showing just such a bank as appears at the east of picture B, in the distance. The rock is St. Peter's Sandstone.

7. Describe the results of the water's work on the rock.

8. Does the water seem to have worn more at its present low stage, or at the flood stage, when it rises as high as the bushes?

D. Looking southwest from near the top of the east side of the Fox valley one mile south of Dayton. The smoke and spires of Ottawa are visible in the distance.

9. What vegetation appears on the valley side at the left?

10. What reason have you for supposing that the fields west of the river were formerly covered with forest?

11. Which side of the valley seems to have the steeper slope?

Look at the topographic map and see if it is so.

NORTH DAKOTA–MINNESOTA. FARGO SHEET

Purpose. To study the characteristics of a newly made lake plain.

Description of the Region. The area shown on this map is a typical part of the plain drained by the Red River of the North. During the glacial period, this area was covered by the waters of Lake Agassiz long enough to receive a deep deposit of clays and sands brought into this lake by the muddy streams from the melting ice sheet. When the ice sheet disappeared, the water drained off into Hudson Bay, leaving the smooth floor of the lake exposed to the action of weathering and erosion.

Location and Extent. 1. In what states does this region lie? To what geographic district does it belong? How many square miles of the region are shown on the map?

Relief and Drainage. 2. Do the contours indicate much or little relief?

3. State the general altitude of the region in the vicinity of Red River at the northern and at the southern border of the map. What is its average slope per mile? In what direction?

4. Name the four largest rivers. What is the general direction of their flow? Why?

5. Are their channels straight or meandering? Why?

6. Are the stream valleys wide or narrow? Deep or shallow?

7. Are the tributary valleys few or numerous? Explain the meaning of the scallops in the 900-foot contour along the Red River just north of Fargo.

8. Are the divides flat, or formed into ridges and hills? Why are they in this form at present?

9. What do the number and depth of stream valleys, the shape of the divides, and the general relief of the region show about the length of time weathering and erosion have been affecting this region?

Culture. 10. How thoroughly has the topography of this area permitted the Land Survey to carry out its rectangular plan for wagon roads?

11. What advantages does this area offer for the construction of railroads?

12. What is the annual rainfall of this region? What industry does nature invite here?

MARYLAND–VIRGINIA. WICOMICO SHEET.

Purpose. To study a portion of the Atlantic Coastal Plain near "Tidewater Virginia."

Description of the Region. This region with its broad tidal rivers and immature drainage is characteristic of the country around Chesapeake Bay and along much of the coast south of New York. The surface was formerly smooth and sloped gently toward the ocean. Beneath the surface are many layers of rock waste consisting of sand, gravel, marl, fuller's earth, etc.

Location and Extent. 1. Along what large river is this region situated? To what geographic district does it belong?

2. What is the scale of miles? How wide is the Wicomico River at Stoddard Point? Is this an average width for the river?

Relief and Drainage. 3. Where, on the sheet, is the land represented as near sea level? Where is the highest land, and what is its altitude?

4. Do any contours cross the Wicomico River? What does this indicate as to its grade?

Have the streams in Zekiah and Gilbert swamps steep or gentle grades, and how can you tell?

5. Note the land (divide) between Zekiah and Gilbert swamps. How wide is it at Dentsville?

How high above the swamps is the crest of the divide at this place? Is the crest higher or lower toward the south?

6. Are the contours on this divide straight or crooked? Does this indicate a smooth or a rough surface? What has caused this?

7. Is the crest of the divide (where the wagon road is located) as rough as the slopes on either side? Why?

Culture. 8. Is the rectangular plan of wagon roads followed here? Give a reason.

9. Does the location of railroads show that the valleys or the divides afford better facilities for traffic?

10. The wagon road northward from Pope Creek village (mouth of Pope Creek) goes directly over the divide. Why does not the railroad follow a similar course?

Profile. 11. **A.** Make a sea-level profile from Pope Creek village northward along the wagon road to Bel Alton, using standard scale. Mark with letter *B* where bridges were probably built.

B. Make profile between same two places along the railroad. Mark with a *C* places where cuts were probably made and with an *F* where fills were probably made.

Advanced Questions. 12. Why is the Wicomico River so wide in proportion to its length?

Why is there so much marsh (salt and fresh) in this region?

13. If this entire region should sink a hundred feet below its present level, what would be the effect upon Zekiah and Gilbert swamps? What present contour would then mark the river's banks?

How would these rivers then compare with the present condition of Wicomico River?

WEST VIRGINIA. CHARLESTON SHEET

Purpose. To study a region of mature surface drainage.

Description of the Region. The region about Charleston, West Virginia, is typical of a broad strip of land lying along the western side of the Appalachian Mountains. The Kanawha River divides this plateau strip into two sections: the section north is called the Allegheny Plateau, and that south, the Cumberland Plateau. The rock consists of nearly horizontal layers of sedimentary origin. Workable layers of coal are found among the layers of rock.

Location and Extent. 1. Give the location of this region. To what geographic district does it belong?

2. What is the exact and the approximate scale of the sheet? What part of a degree wide? How does the area of this sheet compare with that of the sheets previously studied?

Relief and Drainage. 3. What is the contour interval, and what relief does the use of such an interval suggest? Are the contours crowded together or well spaced apart, and what does this indicate as to the steepness of slopes? Are the contours grouped in spots or evenly distributed over the sheet? How, then, do different localities compare in amount of relief?

4. What is the name of the river that occupies the largest valley on this sheet? Which tributary drains the largest area on the sheet?

5. Is any portion of this region a mile square without streams? Are the divides broad or narrow? What do these facts show concerning the drainage of this region (mature or immature)?

6. The altitude of the top of the Kanawha valley at Lock No. 4 is about 1400 feet. How deep is the valley here? At Lock No. 7 the top of the hills along the valley have an altitude of about 1000 feet. What is the depth of the valley here? How wide is the bottom of the valley (the flood plain) at Lock No. 6?

7. How was the broad, deep valley of the Kanawha made? As the small valleys become deeper, will the relief become greater or less?

8. Does the fact that the Kanawha River has a broad flood plain indicate a steep or a gentle grade? What is the total descent of the Kanawha River between Locks Nos. 4 and 7? The distance between these locks is about 25 miles; what is the grade per mile?

Culture. 9. What is the annual rainfall of West Virginia? Give reasons why you think this region is, or is not, good for farming. As forests cover these rugged hills, what industry has probably developed here? What mining industry is carried on among the hills?

10. Do the wagon roads follow the rectangular plan? Give a reason for the fact. Are the roads in valleys or on divides?

Advanced Questions. 11. Do you think the percentage of run-off in this region is small or large, and why?

12. If this region was formerly smooth, as the very even height of the hilltops indicate, why is it now so rough? After the drainage of a region has become mature, what work may the streams continue to do?

The picture shows a part of the Allegheny Plateau lying east of the Charleston region.

1. Does the river here have a straight or a winding course?

2. Are the sides of the valley steep or gentle?

Are they too steep for trees to grow on them?

3. Has the valley a broad or a narrow flood plain?

4. Are the tops of the hills (the sky line) even or uneven?

How have these hills been made?

5. What must have been the condition of this whole region before the river cut its valley?

6. Where are the roads located?

Why there?

KANSAS. CALDWELL SHEET

Purpose. To study a region in the central part of the Great Plains.

Description of the Region. The region represented on this sheet typifies a broad strip of country, somewhat deficient in rainfall, lying east of the Rocky Mountains. The softness of the rock and the climatic conditions have combined to bring the river valleys to an advanced stage of development.

Location and Extent. 1. In what part of Kansas is this region located? To what geographic district does it belong?

2. What is the scale of miles? How does this scale compare with a scale of 1 to 62,500? How wide a strip of country is shown on this sheet?

Relief and Drainage. 3. What is the contour interval, and does it suggest a region of little, of moderate, or of great relief? What relief is indicated by the railroads crossing the country without regard to hills and valleys?

4. Do you find the contours grouped together in spots, or are they very evenly spaced over the sheet, and does this indicate uniform or variable slope? Do you find many small closed-curve contours? Therefore, are there many hilltops here?

5. Are the courses of the larger streams on the sheet straight or winding? Do contours follow closely along the sides of the streams, or is there considerable space between them and the river? Does this show a narrow or a broad flood plain? Are the contours on the slopes of the valley sides close together, as on the La Salle sheet, or are they well spaced? What kind of slope does this fact indicate? As you approach the river is it easy to determine where the valley sides begin? Then would you classify these valleys as "open valleys" or as gorges?

6. Find where the 1200-foot contour crosses the Chikaskia River, also where the next heavy contour up stream crosses it. How many feet of descent does the river have between these two points? Measure as accurately as possible the length of the river between these points and determine the grade per mile.

7. Notice the divide between Chikaskia River and Bluff Creek where a branch of the Missouri Pacific Railroad crosses it. What town is located on the crest of the divide? How high above the Chikaskia River is the town?

8. Does the spacing of the contours indicate a steep or a gentle slope from the town to the river? What kind of slope is indicated by the course of the railroad? Do the contours show that the crest of the divide is sharp or rounded? How do the other divides on the sheet compare with this in general shape?

9. What is the annual rainfall of this region? Are there many or few intermittent streams, and what does this indicate as to the frequency of rains?

Culture. 10. The small relief of this region admits of what plan of wagon roads? Has the relief influenced the direction of the railroads?

11. How many towns are on this sheet? How many lines of railroad? Is the sheet well covered with wagon roads? Do these facts show that this part of the Great Plains is well populated?

Advanced Questions. 12. Give the different characteristics of this region that point to an advanced stage of development.

13. What change would take place in the relief of this region if the annual rainfall should be doubled?

14. Make a sea-level profile along the Missouri Pacific Railroad from Freeport to Elwelf; make horizontal scale same as sheet, and vertical scale 1 cm. = 200 feet, which gives the same vertical exaggeration as the standard scale.

COLORADO. LAMAR SHEET

Purpose. To study irrigation.

Description of the Region. The region represented on this sheet is in the southeastern part of Colorado, about 100 miles east of Pueblo. A number of natural sinks occur here, probably caused by water making caverns in the easily dissolved rock, such as rock salt, gypsum, lime, etc., and the roof caving in. These sinks may be recognized by the presence of shallow lakes which usually go dry during the summer.

Questions. 1. What river crosses the sheet? Which way does it flow? Does it have many or few tributaries?

Do you find many streams on other portions of the sheet? Do these small streams flow all the year?

2. Find the annual rainfall of this region. In what way does this account for the number of streams here?

Does the amount of rainfall seem sufficient for crops? For raising cattle and sheep?

3. Notice the irrigation canals. Follow the course of the Colorado and Kansas Canal. Why was its course made so crooked?

At what altitude does it leave the river? How high above the river is it at the edge of the sheet? Does the water in it flow faster or slower than that in the river? Why?

4. What land can be successfully irrigated by this canal?

What land can be successfully irrigated by the canals on the southern side of the river?

5. Notice the Arkansas Valley Canal. As this begins in the same river, how does it happen that it is so much higher up the valley side than the Colorado and Kansas Canal?

What two reservoirs are used for storing water along this canal? Why are they needful?

What land can be successfully irrigated by this canal?

6. What part of this region seems to be most thickly settled? What is the probable reason? What change in the productiveness of this region is made possible by irrigation?

ARIZONA. KAIBAB SHEET

Purpose. To study a high plateau region.

Description of the Region. This region belongs to a series of plateaus west of the Rocky Mountains. These plateaus are vast blocks of uplifted rock, of which the Kaibab Plateau is one of the highest. The bed rock consists mainly of nearly horizontal layers of sandstone, limestone, and shale.

Location and Extent. 1. In what part of Arizona is this portion of the Grand Canyon of the Colorado River? To what geographic district does it belong?

2. How wide and how long is the sheet in degrees? What is the scale of miles? How does this compare with a scale of $\frac{1}{62500}$? $\frac{1}{125000}$?

Relief and Drainage. 3. What is the contour interval, and what kind of relief does this indicate?

4. Find four plateaus with names. Locate each with respect to the Colorado River, and give the altitude of the highest heavy contour on each. Are the tops of these plateaus smooth or rough?

5. What is the altitude of the bottom of the Colorado Canyon in the central portion of the sheet as shown by the heavy contour close along the river? How far below the top of Powells Plateau is it?

6. Note the two groups of closely spaced contours on each side of the Colorado River between Kanab and Cataract creeks. The outer groups indicate the sides of the old, or outer, valley and the others the new, or inner, valley. How high above the river is the top of the inner valley? How high is the top of the outer valley above the inner gorge? What is the total depth, then, of the Grand Canyon here? How wide is the outer valley here?

7. What is the annual rainfall of this region? Why are so many gorges without water during a large part of the summer?

8. What soon becomes of the water that issues from such springs as Mangum Spring and Big Spring? Why should springs be so carefully mapped in a region like this?

Culture. 9. Do you find many wagon roads, railroads, towns, and other signs of human activity in this region? Give a reason for this condition.

Profile. 10. Use the following data to construct a sea-level profile across the Grand Canyon at a place near the mouth of Cataract Creek. The horizontal scale is 1 in. = 1 mi.; make the vertical scale 1 cm. = 2000 ft. This gives a profile with practically no vertical exaggeration. The first line gives distance from starting point in centimeters, and the second line gives altitude of each station in feet. Make the river channel 4 mm. wide and 25 ft. deep.

Cm.	.0	1.8	1.9	2.6	2.8	7.4	7.6	8.2	9.0	9.4	9.6	14.3	14.4	14.9	15.0	17.0
Alt.	6250	6250	5750	5500	5000	4000	3000	2000	2000	3000	4000	5000	5500	5750	6250	6250

Advanced Questions. 11. If scale of miles is taken as the indication of economic importance, how does this region compare with the others you have studied?

12. Explain why the Colorado River has been able to cut so deep a channel here.

13. Why are springs more abundant on the side of Kaibab Plateau than elsewhere on the sheet?

14. On which plateau would a ranchman be most likely to find grazing and forests? Why?

15. Small tributary valleys to the Grand Canyon are more numerous along the front of the Kaibab Plateau than elsewhere. Give a reason for this.

16. Make a longitudinal profile of the Colorado-Green River, using the following data. In the horizontal scale have 1 cm. = 100 mi., and in the vertical scale have 1 cm. = 2000 ft.

Stations	Distance from Mouth	Altitude above Mouth
Mouth	0 miles	0 feet
Second Sta.	600 miles	1000 feet
Third Sta.	900 miles	3200 feet
Fourth Sta.	1430 miles	4750 feet
Fifth Sta.	1650 miles	6250 feet
Source	1800 miles	7800 feet

Purpose. To study a portion of the Appalachian Mountains in Pennsylvania.

Description of the Region. The region represented on this sheet is typical of the northern Appalachian Mountains. The ridges are the upturned edges of durable sandstones and conglomerates, while the valleys between them have been made in weaker limestones and shales.

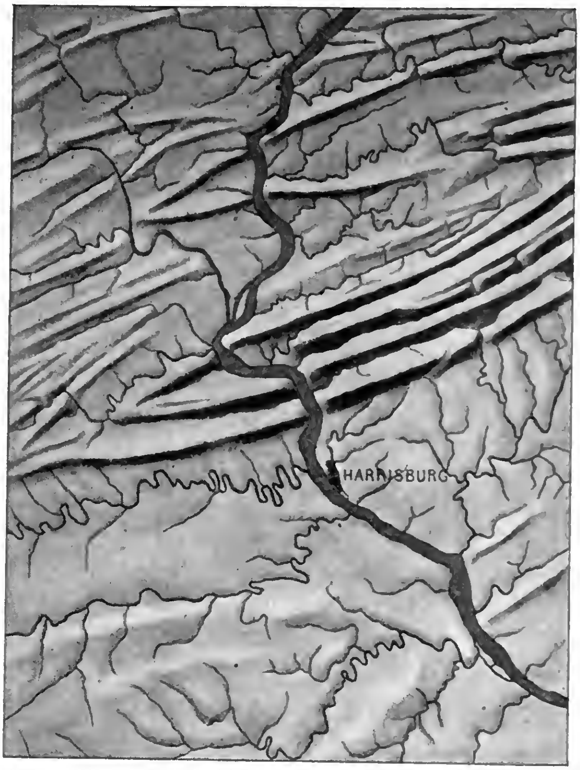
Location and Extent. 1. In what part of Pennsylvania is this region located? To what system of mountains does it belong?

Relief and Drainage. 2. What is the contour interval? Are the contour lines spread evenly over the sheet, or are they grouped, and what does this indicate as to the relief in different places?

3. Name the four prominent ridges shown on the sheet east of the Susquehanna River, and give the elevation of the highest heavy contour on each. About how many miles apart are the crests of the ridges?

4. Do the contours on the sides of the ridges run nearly straight, or are they crooked; and does this indicate smooth or rough slopes? Do many or few streams flow down the sides of these ridges from the crest, and have they cut deep gorges? Are the tops of the ridges composed of sharp peaks, or is the crest line nearly smooth? Draw a line on your paper to represent the crest line of Second Mountain.

5. What direction has the Susquehanna River with respect to the direction of the ridges? Through how many ridges shown in the figure below has the river cut water gaps?



6. How deep is the water gap at Second Mountain? How wide is the gap at the top (at 1200 foot contour)? How wide at the bottom? Is the river wider or narrower at this gap than either above or below it? Give a reason for this.

7. What direction do the tributaries of the Susquehanna River have with respect to the direction of the ridges? In what kind of rock are these streams working? What is the grade per mile of Stony Creek from Watertank to Ellendale? What is the grade of the Susquehanna from the water gap at Second Mountain to just below Sheets Island?

Culture. 8. What is the name of the principal city on the sheet, and what is its political relation to the state? How high above the river are the capitol buildings (center of city)?

9. Is the rectangular plan of wagon roads followed on this sheet? Give a reason. How are the railroads influenced by the relief? Name portions of this region that are suitable for farming.

Profile. 10. Make a sea-level profile across the ridges from the "P" in the name Powell Creek (near Powell Valley) to the "P" in Paxton Creek, using only the contours in the valleys and on the crests of the ridges. Use a vertical scale of 1 cm. = 2000 feet, which gives nearly true proportions.

Advanced Questions. 11. Is the course of the Susquehanna independent of, or dependent upon, the direction of the ridges? Give reason for your answer. What must have been the relief of this region when the river first took its present course?

12. Why are the crests of these ridges so even, instead of being rough like the Rocky Mountains? What evidences do you find that these ridges are being destroyed? (See figure.)

COLORADO. ANTHRACITE SHEET

Purpose. To study a portion of the Rocky Mountains.

Description of the Region. The region represented on this sheet contains no large range of mountains, but is fairly typical of Rocky Mountain topography. Sedimentary rock abounds, and the upturned edges of the more resisting layers form such peaks as Garfield, Peeler, and Mt. Emmons. Outflows of lava are plentiful, and such mountains as Carbon, Axtell, Gothic, and Marcellina are of igneous origin. Lava pouring up through long fissures in the sedimentary rock has formed Anthracite and Ruby ranges. The drainage belongs to the Gunnison-Grand-Colorado River.

Location and Extent. 1. In what part of Colorado is this region located? To what mountain system does it belong?

2. What is the scale of miles? How far from the top of Mt. Carbon to the top of Mt. Axtell? From Mt. Carbon to Mt. Emmons?

3. What does the use of this large scale indicate, as to the economic importance of this region? Give names of places on the sheet that point to various mining activities.

Relief and Drainage. 4. What is the contour interval? Why is it necessary to have a greater interval than on the Harrisburg sheet? Give the greatest altitude of Anthracite Range and of Ruby Range.

5. Do the different ranges and ridges on this sheet extend in the same direction? How does the arrangement here compare with the Appalachian ridges on the Harrisburg sheet? Are the crests of the Ruby and Anthracite ranges even or uneven? Draw a line across your paper that you think represents the crest of Ruby Range, and mark the positions of five high peaks. How does this line compare with the crest line of Second Mountain in Pennsylvania?

6. As you look over the sheet, does it appear that the streams have done little or much work of erosion? How can you tell? What streams have cut deep gorges in parts of this region?

Profile. 7. Make a sea-level profile from the top of Gothic Mountain to the top of Peeler Peak, using a vertical scale of 1 cm. = 2000 ft., which gives a profile with but little vertical exaggeration. Name the different parts of the profile.

Culture. 8. How well is the region supplied with wagon roads? Where have they been located to secure easy grades?

9. How many railroads have been built here? What purpose do they serve?

Advanced Questions. 10. Notice the large number of open valleys or basins on the flanks of the ranges. These at one time contained glaciers, and are known as glacial *cirques*. What characteristics do they have that lead you to think they once contained glaciers?

11. Some of these basins are good examples of *hanging valleys*. One may be seen just north of Cascade Mountain, containing three steps. Two of the levels contain lakes. What is the difference in their altitude? How high is the lower lake above the level next below it? Sketch a longitudinal profile of this whole valley, showing the different steps. Explain how this valley may have been formed.

12. Locate other *hanging valleys*.

CALIFORNIA. SHASTA SPECIAL SHEET

Purpose. To study a young, but inactive, volcano.

Description of the Region. Mt. Shasta, a typical young volcano, is near the southern end of the Cascade Mountains. The secondary cone, Shastina, is of more recent origin than Mt. Shasta proper, and still retains its crater except on the western side, where a lava outflow carried away the rim.

Location and Extent. 1. In what part of California is Mt. Shasta? To what range of mountains does it belong? Give as nearly as possible the latitude and longitude of the top of Mt. Shasta.

2. What is the scale of miles? What is the distance from the top of Mt. Shasta to the top of Shastina? How long is the Sisson Southern Trail, leading from the Southern Pacific Railroad to the top of Mt. Shasta?

Relief and Drainage. 3. What is the contour interval? Does this interval indicate a region of small or of great relief? Of gentle or of steep slopes? What shape do the contours show the volcano to have?

4. How does the closeness of the contours near the top of Shasta compare with those near the base, and, therefore, how does the steepness of slope near the top compare with that near the base?

5. What is the altitude of Mt. Shasta? Of Shastina? How many feet high must one climb going from Sisson to the top of Mt. Shasta? What is the average grade per mile?

6. What two kinds of volcanic material have built up the cone of Mt. Shasta as shown by the names on different parts of the volcano? Have the small cones been roughened by stream action? Does this fact show that they are young or old?

7. On which side of Shasta are the streams most abundant? Least abundant? Which of these streams has the largest valley? How deep is this gorge where the 6000-foot contour crosses the stream? Why do some streams, such as Panther Creek and Inconstance Creek, have a continuous flow in the upper part of their courses and then become intermittent or entirely lost farther down?

Culture. 8. Are there many wagon roads and trails on Mt. Shasta? Why? Explain why the railroad has such a winding course.

Profile. 9. Mt. Shasta is too broad to permit a complete profile on the scale of the map. The following west-east approximate data are given on a reduced scale. Use a vertical scale of 1 cm. = 5000 ft., which gives a slope with little exaggeration. Label the two summits.

Distance from Starting Point, in Centimeters	Altitude, in Feet	Distance from Starting Point, in Centimeters	Altitude, in Feet
0	4,000	8½	14,380
1	4,300	9	12,000
2	5,000	10	10,000
3	5,700	11	8,500
4	6,400	12	7,500
5	8,000	13	6,400
6	10,000	14	5,500
7	12,433	15	4,800
7½	12,000	17	4,000

BOWLDER CLAY, OR TILL

Purpose. To study the composition and properties of the rock waste in a glacial moraine.

Material. A piece of unweathered bowlder clay, a small test tube, a piece of glass, water, hydrochloric acid, a blotter, a hand magnifier.

1. What is the color of the lump of dry clay?

2. Is it firm, or does it easily fall to pieces?

3. What do you see in the lump besides the very fine clay?

Put a half teaspoonful of the clay into a test tube half full of water, cover the end of the test tube with your thumb, invert, and shake gently until the particles are thoroughly separated and suspended in the water. Stand the test tube aside for a few minutes until the suspended particles begin to settle.

4. Does the fine material, or the coarse, settle first?

5. About what fraction of the material is very fine?

To get the fine clay and coarse grains of the lump separated so that you can see them more easily, put a lump the size of a pea on a piece of glass. On it drop three or four drops of water. Crush the lump with your finger and rub it up in the water, adding a few more drops, if necessary, to make a thin mud. Tilt the glass a little and absorb in a blotter the mud that runs off. Let a few more drops of water run over the coarse grains till they are clean. Examine the grains with a magnifier.

6. What different colors do you find in the grains?

7. Are the grains regular, or irregular, in form?

8. Which grains are affected by hydrochloric acid? What kind of rock are they?

9. Put on the glass a little of the fine sediment caught on the blotter and test with hydrochloric acid. What mineral does the test show to be present in the fine sediment?

10. As the fine sediment spreads out in the acid, does it seem uniform in composition, or like the coarse grains, composed of pieces differing in color and size?

11. Do you find in unweathered bowlder clay remnants of decayed plants and animals — as in soil? Give a reason.

12. What facts that you have observed indicate that the glacial clay was produced by the glaciers grinding firm rock to powder, and not by the atmospheric disintegration of rock?

COMPARATIVE STUDY OF GLACIAL AND LAKE (RIVER) PEBBLES

NOTE. Nearly all lake and river pebbles within the glaciated region have been washed from the drift.

1. Does the glacial pebble have sharp angles, or are the angles rounded and obscure? How does the lake (river) pebble compare with it in this respect?

2. Is the general surface of the glacial pebble smooth or rough? How does the surface of the lake (river) pebble compare with it in smoothness?

3. Does the glacial pebble show any markings not found on the lake (river) pebbles? If so, tell what they are.

4. Describe the scratches or striæ on the glacial pebble as regards (*a*) number (large or small) (*b*) depth, (*c*) uniformity of direction.

5. Do you find sets of striæ running at different angles? If so, give a possible explanation.

6. If the lake (river) pebble was once covered with striæ, how may they have been destroyed?

7. How have the striæ on the glacial pebble been protected from wear ever since they were made by the glaciers?

CALIFORNIA. SHASTA SPECIAL SHEET

Purpose. To study the glaciers on Mt. Shasta.

Description of the Region. The snow-crowned peak of Mt. Shasta is very conspicuous in the scenery of northern California. The top, which reaches about 4000 feet above the timber line, is surrounded by several small glaciers.

Questions. 1. What is the altitude of Mt. Shasta? Do you think that the precipitation at this altitude is rain, or is it snow? Why do you think so? Why, then, are glaciers found near the top?

2. How many glaciers are located here? Give name, location, and length of the longest; of the shortest.

3. As strong southwest winds prevail here, where does most of the snow come to rest, and where do you find the largest glaciers? Give another reason for the location of the glaciers.

4. At about what altitude do the glaciers on the northern side melt? Those on the southern side? Why the difference?

5. What different moraines are made by these glaciers?

6. Name two glaciers that occupy well-formed valleys. What one spreads very broadly over the side of the mountain?

From the presence of moraines and high cliffs among the glaciers, what do you think the glaciers are doing to the mountains?

Advanced Questions. 7. What are the sources of the water that forms many of the streams on Mt. Shasta? Some of the stream beds are lined with pebbles, and others not. Why the difference?

8. It is evident that snow falls on Shastina. Why does it not form into glaciers?

WISCONSIN. WHITEWATER SHEET

Purpose. To study a glacial region.

Description of the Region. During the last glacial invasion one lobe of the ice sheet came southward by way of Green Bay and Lake Oshkosh, and another by way of Lake Michigan. In southeastern Wisconsin these two lobes met and formed a kettle terminal moraine. A small part of this moraine extends in a northeast to southwest direction across the southern side of this sheet. The swampy area north of this moraine contains a number of drumlins that were formed underneath the Green Bay lobe.

Location and Extent. 1. Where is this region located? To what geographic district does it belong?

2. What is the scale of miles? What is the distance by railroad from Whitewater to Palmyra?

By wagon road from Palmyra to Oak Hill?

Relief and Drainage. 3. What is the contour interval? Where is the relief greatest? Least?

A. *The Terminal Moraine.* 4. In what part of the sheet is the terminal moraine located? In what direction does it extend? How was it formed?

5. What is the altitude of the swamp in the central part of the sheet just north of the moraine? The altitude of the moraine is about 1000 feet; how much higher than the swamp is it?

6. Is the surface of the moraine rough or smooth? How can you tell?

The "kettles" are shown by *depression* contours. Are there few or many kettle holes? Give the depths of two or three of the deepest. Do they have any particular shape? (See picture of a kettle hole, p. 99.)

7. Is the drainage of the moraine mature or immature? Give a reason for this condition.

B. *The Drumlin Area.* 8. About what fractional part of the region north of the moraine is swamp and what part hills? Are there many or few drumlins here? Under what glacial lobe were they formed?

9. What general shape have these drumlins? Which way do the long axes extend? Which way, therefore, did the glacier move?

Culture. 10. Mention some reasons for believing that the dry land of this region is well settled.

11. Which of the lakes in this region do you think make good summer resorts? Which do not? Give your reasons.

Advanced Questions. 12. Tell why you think this whole region has immature drainage.

13. As drainage matures, how will the farm land increase in quantity? How will it improve in quality? Why?

This picture represents a kettle hole, such as those shown on the moraine in the southeastern part of the Whitewater sheet.

This picture represents a drumlin such as those on the Whitewater sheet.

1. Has this drumlin steep, or gentle, slopes?

2. Does the drumlin appear much worn by water?

3. What does this fact show concerning its age?

NEW YORK. WATKINS SHEET

Purpose. To study a glacial lake and its immediate surroundings.

Description of the Region. The long, narrow lakes in western New York, called Finger Lakes from their resemblance to the fingers of the hand, were made by the deepening and widening of river valleys by glacial lobes moving southward from Lake Ontario. All these lakes have a common outlet through the Oswego River into Lake Ontario.

Questions. 1. What is the average width of the part of Seneca Lake shown on the sheet? What is its altitude?

2. What do the contours show as to the steepness of the shore on both sides of the lake? How high above the lake is the shore at a distance of about ½ mile from the lake?

3. Look at several of the small streams that flow into the lake. In what part of their course is the grade the steepest?

The valleys of these streams are examples of *hanging valleys*. Sketch a longitudinal profile of the creek flowing through Reading Center on the west side of the lake.

4. Does Watkins Glen Creek flow through a hanging valley? How can you tell?

How deep is the glen where the railroad crosses it?

(Pictures of the glen are common and show how the stream is cutting rapidly into the soft shale and sandstone of the region.)

5. What becomes of the sediment brought into the lake by all these streams? How will the width and depth of the lake be affected by it? How many miles of the old lake bed at the southern end have become dry land?

6. What is the origin of the many points along the shore? Why are the largest points at the mouths of the largest streams?

7. What appears to be the future of Seneca Lake? Why do you think so?

8. Make a sea-level profile across the lake near the "a" in Seneca, extending it 2 or 3 miles back on to the upland at each side. Use a vertical scale of 1 cm. = 200 ft. What is the vertical exaggeration?

NEW YORK. NIAGARA SHEET, OR NIAGARA FALLS AND VICINITY

Purpose. To study Niagara River and Falls.

Description of the Region. The region represented on this sheet lies between Lake Erie on the south and Lake Ontario on the north. The land consists mostly of two plains: (1) The lower plain extends from Lake Ontario south to Lewiston, where a line of bluffs runs nearly parallel with the lake; this bluff, or escarpment, was the shore of Lake Iroquois, the glacial enlargement of Lake Ontario. (2) The upper plain extends from this escarpment southward beyond the limits of the sheet. On the lower plain underneath a layer of lake silt is a thick layer of shale, and on the upper plain underneath the glacial drift is first a layer of limestone and then the soft shale that forms the bed rock of the lower plain.

The Whirlpool is thought to have resulted from the Falls cutting into an old valley that had been filled with glacial drift.

A very complete history of the Falls, together with many excellent maps and photographs, is given in Bulletin 45 on "Niagara Falls and Vicinity," published by New York State Museum, Albany, N.Y.

Location and Extent. 1. Locate Niagara Falls with reference to New York state and the Great Lakes.

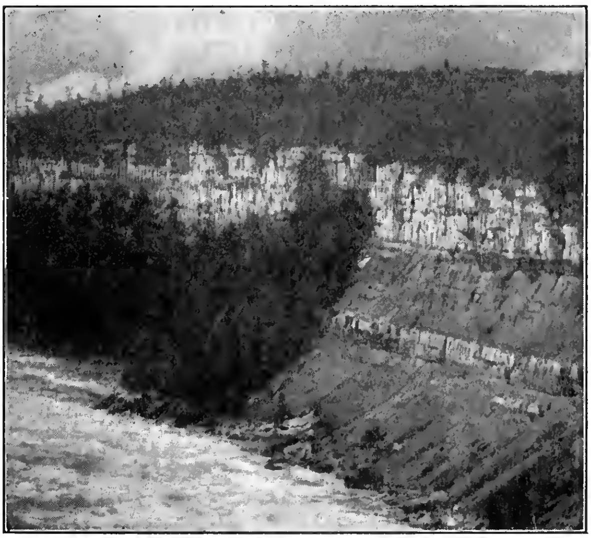
2. What is the scale of miles? What is the distance between the Falls and the Whirlpool? Between the Whirlpool and the foot of the gorge at Lewiston? How long, then, is the gorge?

Relief and Drainage. 3. What is the contour interval? Give in the form of a table the altitudes of the following places: Lake Ontario, foot of the gorge at Lewiston, the Whirlpool, the foot of the Falls, the crest of the Falls.

4. How many contours cross the river on this sheet above Goat Island, and what do they show about the grade of this part of the river? What is the average grade per mile of the river from the head of Goat Island to foot of Falls? From foot of Falls to mouth of gorge? From Lewiston to Lake Ontario? Which one of these four parts of the Niagara River has the steepest grade?

5. Has the river above the Falls a deep or a shallow valley, and how shown? About how deep is the gorge near the foot of the Falls? Near the Whirlpool? How does the depth of the valley change from Lewiston to the Lake?

6. The Falls are now retreating at the average rate of $4\frac{1}{2}$ feet per year. If this rate has been constant, how long has it taken the Falls to wear back from the edge of the escarpment at Lewiston? At the same rate of retreat, how long before the Falls will be at the upper end of Goat Island and so combine the two parts?



Culture. 7. Notice the canal that begins about a mile above the Falls and runs through the village of Niagara Falls. Tell what you can about the use of this and other similar canals on the Canadian side. Why are towns located around the Falls?

Advanced Questions. 8. What condition of rock structure makes the sides of the gorge so steep? (See figure.) If the Falls began at Lewiston near the close of the glacial period, how long ago did that period end?

9. Make a sea-level profile beginning at the southwest corner of the Indian Reservation and going north 4 or 5 miles; for Niagara Falls and Vicinity, use standard scale; for Niagara sheet use vertical scale of 1 cm. = 200 ft. Another profile may be made from Sanborn to Ransomville to show the terraces due to the presence of thin layers of sandstone and limestone within the shale.

10. Beginning at the same point on the cross-section paper, make one profile of the river from the

head of Goat Island to Lewiston, and another of the bank along the river between the two places. The difference between the profiles shows the amount of cutting that has been done by the Falls.

11. From the following data, make a longitudinal profile of the St. Lawrence River, using a horizontal scale of 1 cm. = 100 miles, and a vertical scale of 1 cm. = 1000 ft. What will be the vertical exaggeration?

Stations	Dist. from Mouth	Alt. above Mouth	Depth of Lakes
Mouth	0 miles	0 feet	
Three Rivers	500 miles	0 feet	
Foot Lake Ontario	745 miles	247 feet	} 740 feet
Mouth Niagara River	930 miles	247 feet	
Foot Lake Erie	960 miles	573 feet	} 210 feet
Head Lake Erie	1205 miles	573 feet	
Foot Lake Huron	1305 miles	580 feet	} 700 feet
Head Lake Huron	1568 miles	580 feet	
Foot Lake Superior	1588 miles	600 feet	} 1000 feet
Head Lake Superior	2000 miles	600 feet	
Source St. Louis River	2100 miles	1400 feet	

THE CHICAGO DISTRICT

Purpose. To study the geography and the geology of the Chicago District.

Material. The Chicago Folio, No. 81, and the model of Chicago and vicinity by Siebenthal.

NOTE. The twelve maps in the folio are supposed to be numbered consecutively from 1 to 12, and reference will be made to them in this way.

I. The Chicago District. Make a sketch map showing the location of the district with reference to Lake Michigan (see front outside cover).

II. The Chicago Plain (see p. 1, col. 1). 1. Give its location and shape.

2. La Grange (Fig. 1 and map 1), Homewood, and Glenwood (Fig. 1 and map 4) are on the outer edge of this plain. How many miles wide is the plain at each of these places?

3. Is the plain fairly level, or hilly? (Maps 1 and 4.)

4. What is the approximate altitude of the plain? (See heavy contour maps 1 and 4.) How high is the plain above Lake Michigan? (See figure in brown on the lake.)

5. To what two causes is its flatness mainly due? (P. 6, col. 2.)

6. What superficial rock covers most of the plain? (Pgd. maps 6 and 8 and legend on side of maps.)

7. What material forms the lakeward side of the plain? (Ps. maps 6 and 8.)

8. What sedimentary rock outcrops in places over this plain? (Sn. maps 6 and 8.)

9. Among the most prominent elevations on the plain are Rose Hill (see top of map 6), Blue Island Ridge, and Stony Island Ridge (see top of map 8). Of what is each composed?

III. The Drainage of the Plain. 10. What river drains the northern and central parts of the plain? What river drains the southern part? What, the northwestern? (See p. 1, cols. 3 and 4, and maps 1, 2, and 4.) Into what larger body of water does each river flow?

11. Do the lakes and marshes (maps 3 and 4) indicate a well-drained or a poorly drained plain? What is the stage of erosion?

12. Give the course and use of the Sanitary and Ship Canal — Drainage Canal (p. 1, col. 3, maps 1, 2, and 3).

IV. The Valparaiso Moraine. 13. Where is the Valparaiso moraine located? (Fig. 1.)

14. Find its highest altitude four miles south of Lemont (map 3). How high above Lake Michigan is it here?

15. Locate each center from which ice sheets moved outward during the glacial period, and name each sheet (Fig. 6.)

16. Notice the striæ marked by arrows on the limestone outcrops (maps 5, 6, and 8). In what direction do they show the glacier was moving?

V. Lake Chicago. 17. How was Lake Chicago produced? (P. 7, col. 2.)

18. Where was its outlet? (Fig. 7 and map 3.)

19. What was the shape of the outlet? (P. 7, col. 2, and map 3.)

20. Was the outlet cut down through the moraine and into the bed rock? (Map 7.)

21. How wide at the bottom, and how deep is the outlet at Lemont? (Map 3.)

VI. Stages and Beaches of Lake Chicago. 22. Find Glenwood on map 8. What narrow deposit extending northwest and southeast (Pb.) occurs here? This line marks the *Glenwood Stage* of Lake Chicago, and roughly follows the 640-foot contour. Turn to Fig. 7 and notice this former lake margin. Name the villages now located along it. How high above the present Lake Michigan was Lake Chicago at this stage?

23. The *Calumet Stage* (named from the river) is marked by a broken blue line passing through South Harvey and Oak Glen. What deposit (Pb., map 8) lies along it? Turn to Fig. 11, and name the villages now located along this ancient beach line.

24. The *Tolleston Stage* (named after Tolleston, Ind.) is also represented on map 8 by a broken blue line running from near Hammond to near Blue Island. Notice the heavy contour along this line, and give its height above Lake Michigan. Turning to Fig. 12, name the villages located along this ancient beach.

25. Copy the map, Fig. 7, and add the Calumet and Tolleston beach lines, Figs. 11 and 12. Color

the present area of Lake Michigan blue, the three stages of Lake Chicago three shades of green, and the unsubmerged area brown.

VII. Name the economic products of the district (pp. 12 and 13).

VIII. Vertical Rock Section. The data for the vertical section have been generalized from a number of deep wells in the vicinity of Chicago. Use paper 3 cm. wide and make the vertical scale 1 cm. = 200 ft. Separate the layers of sedimentary rocks by lines across the section at the proper depth, but leave the lower end open, as the crystalline rock extends to great depth. The different formations may be colored or filled with the conventional design (see inside back cover of a Geological Folio).

Name of Formation	Thickness
Glacial Drift	80 feet
Niagara Limestone	320 feet
Cincinnati Shale	200 feet
Trenton Limestone	320 feet
St. Peter's Sandstone	340 feet
Magnesian Limestone	300 feet
Potsdam Sandstone	1100 feet
Crystalline Rock	unknown depth

Draw lines down this section representing the depth of the following wells: —

Lincoln Park	1200 feet deep
Oak Park	2200 feet deep
Lehman Well	2600 feet deep

IX. Horizontal Rock Section. The sedimentary formations beneath Chicago come to the surface (outcrop) between Chicago and Grand Rapids, Wis. The data for this northward horizontal section have also been generalized in order to make the section as simple as possible. In the horizontal scale, let 1 cm. = 10 mi. and in the vertical scale 1 cm. = 500 ft. First draw a sea-level line on the cross-section paper, then lay off the scales. Locate dots for Chicago (altitude 600 feet) and for Grand Rapids 220 miles northward, where the crystalline rock outcrops (altitude 1000 feet), and connect these dots with a line. Along this surface line locate dots for the outcrops of each formation, and beneath Chicago locate dots for their altitude. Connect the corresponding dots, and label or color the different formations.

Name of Formation	Altitude of Under Side of Formation at Chicago	Distance from Chicago of Under Side of Outcrop
Niagara Limestone	200 feet	70 miles
Cincinnati Shale	0 feet	85 miles
Trenton Limestone	— 320 feet	105 miles
St. Peter's Sandstone	— 660 feet	122 miles
Magnesian Limestone	— 960 feet	140 miles
Potsdam Sandstone	— 2060 feet	220 miles
Crystalline Rock	unknown depth	unknown distance

Represent the same three wells in this section.

EXPERIMENTS WITH CITY GAS

Purpose. To study a familiar gas to learn :—

(1) Whether it has a color;

(2) Whether it will burn;

(3) Whether it will allow other substances to burn in it.

Material. Pan of water, glass jar or bottle with wide mouth, a piece of cardboard or a glass plate to cover the jar, rubber tube, wire, matches, candle, supply of city gas.

Operation and Result. Fill the jar with water, then, holding the glass plate carefully over its mouth, quickly place it upside down in the pan of water, and withdraw the glass plate.

1. What now fills the jar?

Connect the rubber tube with the gas jet, and, placing the other end under the mouth of the jar, allow the gas to run into it until all the water is driven from it. Turn off the gas, withdraw the tube, slip the glass plate again under the mouth of the jar, and, holding it firmly, lift out the jar and place it right side up on the table.

2. What now fills the jar?

3. What is the color of the gas?

Fasten a candle to a wire two or three feet long, and light it. Remove the glass plate and, by means of the wire, quickly lower the burning candle to the bottom of the jar, keeping the hands a foot or more away from it.

4. Does the gas burn?

5. Does the candle continue to burn?

6. Explain the action of the candle.

7. Write a sentence stating what you have learned about each of the three points given as the purpose of this experiment.

Drawing. On the lower part of this page, draw the apparatus used, showing the results of lowering the candle into the jar.

EXPERIMENTS WITH OXYGEN

Purpose. To prepare the gas oxygen and to learn: —

(1) Whether it has a color;

(2) Whether it will burn;

(3) Whether it will allow other substances to burn in it.

Material. Large test tube, sodium peroxide, water, long splinter of wood or sticks of charcoal, picture wire, matches.

Operation and Result. Fill the test tube about ½ inch deep with sodium peroxide, and pour a little water on it.

1. What happens in the tube?

The cause of this is that the water acts chemically on sodium peroxide, setting oxygen gas free.

2. What is the color of the gas given off? (Do not mistake the fine spray of water for oxygen.)

3. Thrust a match or splinter, burning with a small flame, into the tube. What effect on the flame?

Does the gas burn?

4. Heat a charred splinter or a stick of charcoal until it glows, and then hold it in the tube. What occurs?

5. Hold a glowing charcoal stick in the air a short time. What occurs?

If necessary, renew vigorous action in the tube by pouring in a little more water.

6. Fasten a small splinter in the end of a straight piece of picture wire. Light and hold in the tube. What occurs?

7. Compare the action of oxygen with that of city gas.

8. What advantages result from having the atmosphere composed partly of oxygen?

Drawing. On the lower part of this page, draw the apparatus, showing the result from operation number 4.

EXPERIMENTS WITH NITROGEN

Purpose. To secure a quantity of nitrogen gas from the atmosphere and to determine:—

(1) Whether it has a color;

(2) What proportion of the air it constitutes;

(3) Whether it will burn;

(4) Whether it will allow other substances to burn in it.

Material. Pyrogallic acid, six-inch test tube, glass dish half filled with water, matches, ruler, potassium hydroxide.

Operation and Result. Dissolve a piece of pyrogallic acid, the size of a pea, in about a tablespoonful of water in a test tube. Add a tablespoonful of strong potassium hydroxide solution, and close the tube tightly with the thumb.

1. What substances now fill the tube?

2. Measure and state the depth of each.

3. Shake the tube thoroughly for a short time, and, holding it upside down with its mouth below the surface of the water in the dish, remove the thumb. What does the water do?

The cause is that the acid absorbs the oxygen. The vacancy thus made is filled by the water pushed in by the pressure of the outside atmosphere. The gas left in the tube is nearly pure nitrogen. The small quantities of argon, water vapor, and carbon dioxide which are mixed with the nitrogen do not affect its color or the other characteristics investigated below. Replace the thumb over the mouth of the tube, take it from the dish, and hold it right side up.

4. What is the color of nitrogen?

5. Measure, and state the depth of the gas.

6. The nitrogen now left is about what proportion of the air caught at first in the tube?

7. Removing the thumb, lower a burning match stick into the tube. Does the stick continue to burn?

8. Does the nitrogen burn?

9. How does the action of nitrogen compare with that of city gas?

10. Compare its action with that of oxygen.

Drawing. On the lower part of this page, draw a test tube and indicate the depth of air in it at first; also the depth of nitrogen left from it.

EXPERIMENTS WITH CARBON DIOXIDE

Purpose. To prepare carbon dioxide and to learn: —

(1) Whether it has color;

(2) Whether it will burn;

(3) Whether it will allow other substances to burn in it;

(4) How to use the test that distinguishes it from other gases.

Material. Test tube, dilute hydrochloric acid, small pieces of marble, matches, rubber cork fitted with a short glass tube ending in a short rubber tube, bottle of limewater.

Operation and Result. Put the marble in the test tube, and pour a little acid on it.

1. What happens in the tube?

The cause of this is that the acid acts on the marble, setting carbon dioxide free.

2. What is the color of the gas?

Lower a burning match stick into the gas.

3. Does the stick continue to burn?

4. Does the gas burn?

5. Which of the three gases previously studied does carbon dioxide most resemble?

If the reaction has ceased, add more acid. Place the cork with its connected tubing in the test tube, and let the free end of the rubber tube dip in the bottle of limewater. Allow the gas to bubble through it a short time.

6. What happens to the limewater?

This gas is the only one in the atmosphere that affects the color of limewater.

7. Why is this test necessary to distinguish this gas from nitrogen?

8. What other test will distinguish this gas from oxygen?

Drawing. On the lower part of this page, draw the entire apparatus used when trying the limewater test.

LIGHT. THE COLORS IN SUNLIGHT

Purpose. To study the colors that compose white sunlight.

Material. Glass prism, sheet of white cloth or paper, mirror, sunlight.

Operation. Paste a piece of paper on one face of a prism and hold this face horizontally and uppermost in the sunlight. Instead of passing through the prism to the floor, the light will bend away, and can be made to fall on a piece of white cloth or paper hung on the opposite wall of the room. Instead of the white sunlight, it will furnish the colors of the rainbow. This is called the spectrum. The colors will appear brighter if the room is darkened, and a sunbeam is admitted through a hole in the shutter.

1. What color appears at the bottom of the spectrum? At the top?

2. Name all the colors you can see in the order in which they appear from the bottom to the top of the spectrum.

3. Make a diagram to show the ray of sunlight passing through the prism and spreading out to form the colors on the screen. Which color has been bent the most from the original path of the sunbeam? Which color has been bent the least?

4. Hold a hand mirror near the prism so as to reflect the spectrum on a wall or ceiling. Give a rapid vibrating motion to the mirror so that the spectrum moves to and fro very quickly in the direction of its length, and forms a streak of light. What is its color? What has become of the spectrum?

5. Observe the sunrise and sunset colors, and report their arrangement. Which color of the spectrum is below? Explain.

6. Observe the colors in a rainbow. Report the arrangement of colors, and the location of the sun and of the rainbow with regard to your position. Give drawings.

LIGHT. ABSORPTION OF COLORS

Purpose. To learn how some of the colors of the sunlight may be absorbed by passing through a substance or by being reflected from it.

Material. Flat-sided bottle, soap solution, piece of smoked glass.

Operation. Fill a flat-sided bottle with water in which laundry soap has been dissolved. Look through it toward the sunlight while slowly rotating it.

1. What colors come through it to your eye?

2. Hold the bottle toward some dark object, as the blackboard, so that the light is reflected from the soap solution to you. What is the color?

3. Then what colors have been absorbed by the soap solution?

The soap solution acts like the atmosphere in allowing one or two colors to pass through it easily, and in reflecting another color.

4. What seems to be the color of the sun when its light comes to us through a clouded or hazy sky?

5. Must the deep blue color of the northern sky be due to sunlight coming through it, or the reflection from particles in the atmosphere?

6. Look toward the sun through the smoked glass. What is the sun's color when seen through a part of the glass that has been heavily smoked? Lightly smoked?

7. Does the sunlight, in reaching you, pass through more of the atmosphere's smoke and dust at noon or at sunset?

What effect has this upon the color?

ATMOSPHERIC PRESSURE

Purpose. To determine whether the atmosphere exerts pressure.

Material. A tin can with a small mouth, a cork to fit it, water, gas burner, support, glass thistle tube with a short rubber tube attached, sheet of dentists' rubber, string.

Operation and Result. A. Put a little water in the can and support it over a lighted burner until the water has boiled vigorously for a few minutes. Turn out the burner and, at the same moment, close the can firmly with the cork. Allow the can to cool, and note what happens. The cooling may be hastened by sprinkling water on the can.

1. Describe the result.

2. What did the steam, rising from the surface of the water, do to the air in the can?

3. When the can cooled, what became of the steam?

4. What made the can collapse?

5. Make a section drawing of the can when the water was boiling. By means of arrows show the direction in which the steam moves within the can.

B. Lay a sheet of dentists' rubber over the mouth of a thistle tube, and tie it fast with a string.

6. Blow into the tube. Is the dentists' rubber pushed outward or pulled outward?

7. With the mouth, draw air out of the thistle tube, and pinch the attached rubber tube tightly together. Is the dentists' rubber pulled inward or pushed inward?

State why you think so.

8. Still pinching the rubber tube tightly, turn the thistle tube in various directions. In how many directions does the air exert pressure?

In what directions does the pressure seem to be equal?

9. Make a drawing of the apparatus, showing the result of drawing out the air, using arrows to show the direction of air pressure.

COLUMNS OF MERCURY AS INDICATORS OF AIR PRESSURE

Purpose. To learn how columns of mercury may be used to indicate air pressure.

Material. Mercury, bottle fitted with a two-hole stopper, rubber tube, a short and a long glass tube to fit the holes in the stopper, two glass tubes of the same length but of different diameters, a T-tube having short rubber tubes attached.

Operation and Result. Fill the bottle an inch or two deep with mercury. Push the short glass tube barely through one hole of the stopper. Push the long tube far enough through the other hole to reach to the bottom of the bottle. Place the stopper in the bottle.

1. How high does the mercury stand in this long tube?

2. Attach the rubber tube to the short glass tube, and blow through it into the bottle. What does the mercury do? Why?

3. What determines the height of the mercury?

4. Remove the rubber tube and attach it to the long tube. With the mouth, draw the air out of the tube. What does the mercury do? Why?

5. Make a section drawing of the apparatus to show the result in question 4, using arrows to show where the air exerts pressure.

6. Remove the stopper. Stand the two tubes having different diameters vertically in the bottle, and connect their upper ends with the T-tube. With the mouth, draw the air from the T-tube and observe the result. Does the mercury rise to the same level or to different levels?

7. If one of the tubes had been one inch square, would the mercury have risen to the same height in it as in the other tube?

8. Make a section drawing of the apparatus described in question 6, and show the result of the experiment.

MAKING A MERCURIAL BAROMETER

Purpose. To make a mercurial barometer.

Material. A glass tube about 36 inches long closed at one end, glass tumbler, mercury, glass funnel fitted with a short rubber tube ending in a short pointed glass tube, ruler, support.

Operation and Result. Place the glass tube, open end up, in the support.

1. What now fills the tube?

Tightly pinching the short rubber tube, fill the funnel half full of mercury, and, inserting the pointed tip in the long glass tube, allow a fine stream of mercury to run until the tube is completely filled. Holding a finger firmly over the open end of the tube, invert it into a glass cup filled about an inch deep with mercury. Holding the tube erect, and watching carefully the upper end of the mercury, remove the finger.

2. Describe the result.

3. Measure and state how many inches high the mercury stands above the mercury in the cup.

4. Is there any air in the space in the upper part of the tube? State why you think so.

5. Does the weight of any substance bear on the surface of the mercury in the cup?

6. What, therefore, must hold up the mercury in the tube?

7. Why must the barometer tube be closed at the top?

8. If you had used a square barometer tube 1 inch across, and 36 inches long, how high would the column of mercury have stood?

9. Since 1 cubic inch of mercury weighs about $\frac{1}{2}$ pound (strictly .49 pound), what does this experiment show the weight of the air to be on 1 square inch of surface?

10. Carefully make a drawing of the apparatus, showing the result.

THE ACTION OF A BAROMETER

Purpose. To learn the action and practical use of a barometer.

Material. The barometer made in the previous experiment, a wide-mouth Mason jar, a rubber cork having a short glass tube through it to which is fitted a rubber tube two or three feet long, wax, strong string.

Operation and Result. Break the porcelain plate out of the lid of the jar. Punch two holes in the metal top, one slightly larger than the barometer tube, the other large enough to hold the rubber stopper; or use a wide-mouth bottle with a two-hole rubber stopper.

Tie the cord around the glass cup (a small beaker works nicely) and lower the barometer into the jar. Slip the cover down over the barometer tube and screw it tightly on the jar. Carefully seal the opening around the barometer tube with wax or chewing gum. Push the cork holding the short tube tightly into the other hole.

1. Blow into the rubber tube. What does the column of mercury do? Why?

2. Draw air out of the tube. What does the mercury do? Why?

On this page draw a vertical section of the entire apparatus. Mark and name the place where the mercury stood (*a*) at the beginning of the experiment, (*b*) after blowing more air into the jar, (*c*) after drawing some air out of the jar.

CONDITIONS AFFECTING EVAPORATION

Purpose. To learn the conditions affecting evaporation.

Material. Tin cups or beakers, small pan, glass plates, tumbler, water, piece of iron, gas burner.

Operation and Result. **A.** Put five drops of water on a glass plate and place it on a warm piece of iron. Put the same amount on another glass plate and place it on the desk. Be careful to keep both plates away from a draught.

1. Which evaporates faster? Why?

B. Secure two other glass plates and place five drops of water on each. Place one plate in a draught or fan it some minutes.

2. Which evaporates faster? Why?

C. In two small cups or beakers place equal amounts of water. Cover one cup with an inverted tumbler.

3. What collects on the inside of the tumbler?

4. Is the air within the tumbler damp or dry?

5. From which cup does water evaporate faster? Why?

D. Put equal amounts of water into a pan and into a small cup (enough to cover the bottom of the pan). Allow the vessels to remain close together until you have clearly determined from which vessel the water evaporates faster.

6. What causes the difference?

In one sentence, state the four conditions learned from this experiment, that aid evaporation.

EFFECTS OF EVAPORATION

Purpose. To learn how the temperature of an object is affected when a liquid evaporates from its surface.

Material. Two thermometers of the same style and size, sulphuric ether or alcohol, water.

Operation and Result. First note the temperature of the thermometer, then put drop after drop of ether on the bulb, recording the temperature after each drop has evaporated.

1. What is the general effect on the thermometer? Is the change rapid or slow?

2. Where does part of the heat come from that is absorbed by the ether in evaporating?

Allow drops of water as warm as the room to evaporate on the bulb of another thermometer. Record the temperature after each drop.

3. Compare the change in temperature with that caused by the evaporation of ether.

4. Draw the thermometers on the lower part of this sheet, indicating the temperature at the beginning and at the end of the experiment with the ether, and also with the water.

CONDENSATION OF WATER VAPOR

Purpose. To learn the conditions that cause the condensation of vapor.
Material. Erlenmeyer flask, water, gas burner, glass plate, bright tin cup, salt, ice or snow.
Operation and Result. **A.** Heat some water in a flask until it boils.

1. What is the color of the vapor or steam in the flask?

2. What shows that a change occurs in the steam as it rises in the air? What causes the change?

3. Hold a cool glass plate just above the flask. What does it do to the vapor? Why?

4. Which part of this experiment illustrates the formation of fog off the coast of Labrador?

5. Which part illustrates the formation of fog on a mountain slope?

B. Thoroughly dry the outside of the cup and half fill it with water. Put in some ice or snow, a little at a time, and stir with a thermometer.

6. What forms on the outside of the cup?

7. Where does it come from?

8. Why does it form?

9. At about what temperature is the cup when condensation begins? (This is called the "dew point.")

10. In a cup dry outside, place some finely broken ice or snow mixed with salt. Stir with a thermometer and note the temperature when frost forms on the outside. Did dew form on the outside before the frost appeared?

11. Would dew form before frost in very dry weather?

12. What is the difference between frozen dew and hoarfrost?

FORMATION OF FOG AND CLOUD

Purpose. To learn how the moisture and the temperature of the air are affected by changes in the pressure of the atmosphere.

Material. Large bottle, two-hole rubber stopper, thermometer, water, matches, air pump or bicycle pump, and rubber tubing.

Operation and Result. Put a little water in the bottle to furnish moisture. Insert the thermometer in one hole of the stopper so that the bulb will be within the bottle. Through the other hole, insert the tube and connect it with a bicycle pump or atomizer bulb. Pump air into the bottle and then suddenly disconnect the tube.

1. What does the surplus air do? What does some of the vapor do?

Drop a burning match into the bottle to supply a little smoke or "dust," and repeat the operation.

2. What result? Why different from the first trial?

3. Pump air in again. What effect on the thermometer? On the fog? Explain both.

4. Since rising air expands, why do upward-moving currents of air produce clouds and rain?

5. Draw the apparatus on this sheet.

MOISTURE IN THE ATMOSPHERE. RELATIVE HUMIDITY

Purpose. To determine to what extent the air of the room is saturated.

Materials. Two thermometers, piece of cardboard a little longer than the thermometers, vial, small piece of muslin, water, thread.

Directions. Wrap one end of the muslin around the bulb of one thermometer, tying it with thread so that the muslin shall hang down two or three inches like a wick. Tie the thermometer and the vial to the cardboard so that the wick shall hang in the vial. Fasten the dry-bulb thermometer to the same cardboard. Wet the muslin and fill the vial with water that has been standing in the room long enough to have the room's temperature. Fan the thermometer and note the readings.

1. Which thermometer shows the cooler temperature? Why does it?

2. Would the water evaporate from the cloth faster in dry or in damp air? Then would the thermometers differ more in dry or in damp air? Why?

3. If the thermometers are not fanned, will the air around them remain as dry as the air throughout the room? Explain.

4. Of what does the dry thermometer show the temperature? Does fanning change it?

The following table will show to what per cent the air is saturated. In the left-hand vertical column, find the temperature registered by the dry thermometer. At the top of the vertical columns, find the number which shows the difference in the readings of your two thermometers. From this number, follow down the column to the line indicated by the dry thermometer. The figure at the intersection shows the per cent of saturation.

TABLE FOR FINDING RELATIVE HUMIDITY — PERCENTAGES

Dry Therm. (Air Temp.)	Difference between Dry- and Wet-bulb Thermometers																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
30	89	78	68	57	47	37	27	17	8												
32	90	79	69	60	50	41	31	22	13	4											
34	90	81	72	62	53	44	35	27	18	9	1										
36	91	82	73	65	56	48	39	31	23	14	6										
38	91	83	75	67	59	51	43	35	27	19	12	4									
40	92	84	76	68	61	53	46	38	31	23	16	9	2								
42	92	85	77	70	62	55	48	41	34	28	21	14	7	0							
44	93	85	78	71	64	57	51	44	37	31	24	18	12	5							
46	93	86	79	72	65	59	53	46	40	34	28	22	16	10	4						
48	93	87	80	73	67	60	54	48	42	36	31	25	19	14	8	3					
50	93	87	81	74	68	62	56	50	44	39	33	28	22	17	12	7	2				
52	94	88	81	75	69	63	58	52	46	41	36	30	25	20	15	10	6	0			
54	94	88	82	76	70	65	59	54	48	43	38	33	28	23	18	14	9	5	0		
56	94	88	82	77	71	66	61	55	50	45	40	35	31	26	21	17	12	8	4		
58	94	89	83	77	72	67	62	57	52	47	42	38	33	28	24	20	15	11	7	3	
60	94	89	84	78	73	68	63	58	53	49	44	40	35	31	27	22	18	14	10	6	2
62	94	89	84	79	74	69	64	60	55	50	46	41	37	33	29	25	21	17	13	9	6
64	95	90	85	79	75	70	66	61	56	52	48	43	39	35	31	27	23	20	16	12	9
66	95	90	85	80	76	71	66	62	58	53	49	45	41	37	33	29	26	22	18	15	11
68	95	90	85	81	76	72	67	63	59	55	51	47	43	39	35	31	28	24	21	17	14
70	95	90	86	81	77	72	68	64	60	56	52	48	44	40	37	33	30	26	23	20	17
72	95	91	86	82	78	73	69	65	61	57	53	49	46	42	39	35	32	28	25	22	19
74	95	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30	27	24	21
76	96	91	87	83	78	74	70	67	63	59	55	52	48	45	42	38	35	32	29	26	23
78	96	91	87	83	79	75	71	67	64	60	57	53	50	46	43	40	37	34	31	28	25
80	96	91	87	83	79	76	72	68	64	61	57	54	51	47	44	41	38	35	32	29	27
82	96	91	87	83	79	76	72	69	65	62	58	55	52	49	46	43	40	37	34	31	28
84	96	92	88	84	80	77	73	70	66	63	59	56	53	50	47	44	41	38	35	32	30
86	96	92	88	84	80	77	73	70	66	63	60	57	54	51	48	45	42	39	37	34	31
88	96	92	88	85	81	78	74	71	67	64	61	58	55	52	49	46	43	41	38	35	33
90	96	92	88	85	81	78	74	71	68	64	61	58	56	53	50	47	44	42	39	37	34
92	96	92	89	85	82	78	75	72	69	65	62	59	57	54	51	48	45	43	40	38	35
94	96	92	89	85	82	78	75	72	69	66	63	60	57	54	52	49	46	44	41	39	36
96	96	93	89	86	82	79	76	73	70	67	64	61	58	55	53	50	47	45	42	40	37
98	96	93	89	86	82	79	76	73	70	67	64	61	58	56	53	51	48	46	43	41	39
100	96	93	90	86	83	80	77	74	71	68	65	62	59	57	54	52	49	47	44	42	40

Test the humidity on five different dates and record as follows:—

Date	Temp. of the Air (Dry Ther.)	Wet-bulb Reading	Difference in Temperature	Per Cent of Saturation (Relative Humidity)

MOISTURE IN THE ATMOSPHERE — ABSOLUTE HUMIDITY

Purpose. To determine the actual weight of water vapor in one cubic foot of air.

The amount of water vapor in one cubic foot of saturated air changes with the temperature. The actual amount at different temperatures is shown in grains in the following table. One grain of vapor condensed to water would form a drop about the size of a grain of wheat. In the vapor form it occupies a much larger space.

GRAINS OF SATURATED WATER VAPOR PER CUBIC FOOT

At 0°, .5 grain	At 40°, 2.8 grains	At 80°, 11.0 grains
At 10°, .8 grain	At 50°, 4.0 grains	At 90°, 14.8 grains
At 20°, 1.2 grains	At 60°, 5.7 grains	At 100°, 19.8 grains
At 30°, 2.0 grains	At 70°, 8.0 grains	

Problems. 1. What is the largest number of grains of water vapor that one cubic foot of air can hold at 0°? 30°? 50°? 70°? 100°?

2. How many additional grains of vapor would a cubic foot of air be able to hold if warmed from 20° to 30°? If warmed from 90° to 100°?

3. When saturated air cools, all the vapor it cannot hold condenses to snow or water. How many grains of moisture would be condensed from one cubic foot of saturated air if it cooled from 90° to 80°? If from 40° to 30°? If from 10° to 0°?

4. If 1200 cubic feet of saturated air cools from 50° to 10°, how many grains of water and how many of snow will be formed?

5. Is the air able to contain more vapor near the equator or near the poles? At which of these places would cooling produce a heavier rainfall?

6. If air were 50% saturated, how many grains of vapor would be in one cubic foot of air at 50°? At 90°?

7. With a relative humidity of 60% and a temperature of 70°, how many grains of water vapor in 500 cubic feet of air? In the air of your schoolroom under the same conditions?

8. San Francisco and Independence, Cal., have the same average temperature of 60°. The relative humidity of the former is 77%, and of the latter, 37%. Notice their location on a map and explain this difference in amount of moisture. How many grains of vapor in one cubic foot of air at each place? In which place would cooling the same number of degrees produce the heavier rainfall?

9. The average temperature of Chicago is 50°, and of Yuma, Ariz., is 70°. The average relative humidity of the former is 77%, and of the latter, 49%. What is the average weight of water vapor in a cubic foot of air at each place? Which has the greater amount? Why, therefore, has Chicago a much heavier rainfall than Yuma?

10. On a sheet of cross-section paper, draw a chart to show how much more vapor the air can hold as it becomes warmer. Let the lowest horizontal line represent the temperature of zero degrees. Let one small square vertically represent one degree. Write the proper degree of temperature in the side margin, at the end of each heavy horizontal line. To show the amount of water vapor, let one centimeter horizontally represent one grain. Label the heavy line at the binding margin "0 grains," the next heavy vertical line "1 grain," etc., across the top of the sheet. Using the above table, place a dot to show the number of grains of water vapor that air can hold at each temperature given. Connect these dots with a curving line, and color the space between it and the binding margin. Label it "Grains of Water Vapor Air can hold at Different Temperatures."

EXPERIMENTS WITH HEAT

A

Purpose. To learn the effect of heat upon the size of a solid.

Material. Solid brass ball, ring just large enough to allow the ball to pass through it, gas burner.

Operation and Result. Note how closely the ring fits the ball. Heat the ball for a few minutes, testing its size at frequent intervals by trying to pass it through the ring.

1. What do these tests prove?

Allow the ball to cool, testing its size at frequent intervals.

2. What do these tests prove?

3. Similar changes in size are caused by temperature changes in rocks, glass, and other solids. Explain why the outside layer sometimes snaps off from a rock exposed to the sun.

B

Purpose. To learn the effect of heat upon the size of a liquid.

Material. Colored water, Erlenmeyer flask, one-hole rubber cork, glass tube at least 15 inches long, iron support, wire gauze, gas burner, rubber bands, foot ruler.

Operation and Result. Fill the flask with colored water. Push the long tube nearly through the cork. Adjust the cork in the flask so that the water shall rise a short distance in the tube. With the rubber bands, fasten the ruler to the long tube with its zero end even with the top of the column of water. Lay the wire gauze on the iron support, placing the flask on it, and a lighted burner under it.

1. What is the first brief effect on the height of the water? Explain this.

2. Continue to warm the water. Note the general effect, or record the time required for each increase of one half inch.

3. Allow the water to cool for a time and note the effect.

4. What effect has heat upon the volume of the water?

Upon its density? Upon its weight per cubic inch?

5. On the margin of this paper, carefully draw the apparatus used in this experiment, showing the height of the water before and after heating.

6. If mercury, alcohol, and other liquids were substituted for the water in this experiment, they would behave in a similar manner. Explain the action of a common thermometer.

C

Purpose. To learn the effect of heat upon the volume of a gas.

Material. A hollow glass globe with glass tube attached; or a flask (or large test tube) fitted with a rubber cork through which passes a glass tube; cup of colored water; gas burner.

Operation and Result. Hold the apparatus so that the end of the glass tube dips in the colored water.

1. What now fills the globe (or flask)?

2. Warm the globe with the hands. What happens in the water?

3. Carefully bring the lighted burner near the globe. What effect do you notice? Explain it.

4. Keeping the end of the tube in the water, allow the globe to cool. What does the water do?

What must the air in the globe be doing?

5. Clearly state the effect of heat upon the volume of a gas.

6. What must be the effect upon its density?

7. In the margin draw the apparatus.

D

Purpose. To learn how heat travels through solids.

Material. Bits of wood, paraffin or wax, metal rod or wire, gas burner, cardboard.

Operation and Result. Dip the bits of wood in wax or melted paraffin, and attach them to the rod, placing them one inch apart. Carefully shielding the attached pieces from the direct heat of the burner by means of the cardboard, heat one *end* of the rod.

1. What do the bits of wood do? What does this prove about the heat?

2. What name is applied to this method of heat movement?

3. Where in nature does heat travel through solids?

4. On the lower part of this sheet, make a drawing of the apparatus.

E

Purpose. To learn how heat travels through liquids.

Material. Long pan, gas burner, bits of paper, thermometer, water.

Operation and Result. Nearly fill the pan with water and support it a few inches above the desk. Let it stand until the water is perfectly quiet, then sprinkle the bits of paper on the water. Hang a thermometer in the water at one end of the pan, and place a lighted burner under the other end.

1. What does the water begin to do? How do you know it?

2. As the water near the burner becomes warmer, does it expand or contract? Does it become heavier or lighter?

3. What has this change to do with the movement of the water?

4. How is the thermometer affected? If desired, record the temperature every few minutes.

5. How does the heat get to the thermometer?

6. What name is applied to this method of heat movement?

7. Name some countries bordering the ocean that have heat brought to them from equatorial regions by this method.

8. In the margin draw the apparatus.

F

Purpose. To learn one method by which heat travels through gases.

Material. Candle, matches, shallow pasteboard box, two Argand lamp chimneys, touch paper (paper soaked in a solution of saltpeter and dried) or any other material that gives off much smoke when burning.

Operation and Result. Near each end of the cover of the box, draw a circle as large as the base of the lamp chimney. With a pencil, punch as many holes as possible within the area of each circle. Put a lighted candle in the center of one group of holes, and then place the chimneys on the circles. Light the touch paper and hold it above each chimney in turn.

1. What does the air in the chimneys do, and how do you know it?

2. As the air near the candle becomes warm, does it expand or contract? Does it become lighter or heavier? Why does it move?

3. Hold a hand above each chimney. Which is the warmer? Explain how heat gets to your hand, and give the proper name to this method of heat movement.

4. In what part of your apparatus does the air illustrate the movement of the air in the neighborhood of the earth's heat equator?

5. Where does the air illustrate the trade winds blowing toward the equator?

6. Where and how does it illustrate the air in the tropical calms?

7. Draw a vertical section of your apparatus, and with arrows show the movement of the air.

G

Purpose. To learn whether heat travels through a vacuum.
Material. Electric current; incandescent lamp from which the air has been completely exhausted.
Operation and Result. Hold the bulb in your hand and turn on the current.
1. What change in temperature do you notice?

Although the bulb has no air in it, yet its space is filled with the mysterious *ether* that extends through the universe.
2. How does this experiment illustrate the earth's receiving light and heat from the sun?

3. What name is applied to this method of heat movement?

4. By this method, heat (and light) travels 186,000 miles per second. State the sun's average distance from us, and determine how many minutes are required for the sun's rays to reach the earth.

H

Purpose. To determine whether dark- or light-colored surfaces absorb heat most readily.
Material. Two thermometers, sheet of cardboard, small piece of black and of white paper.
Operation and Result. Tie the thermometers to the cardboard about an inch apart, and fasten a piece of black paper over one bulb and a piece of white paper over the other bulb. Lay the apparatus in the sunshine and record the temperature of each at frequent intervals.
1. Which color absorbs heat most readily?

2. What proves the other color to be a better reflector?

RELATIVE AMOUNTS OF HEAT RECEIVED FROM THE SUN

Purpose. To study the heating power of the sun's rays when they fall on the earth at different angles.

Turn the binding edge of a sheet of cross-section paper toward you, and let the heavy line running parallel with the lower lengthwise edge, and two centimeters from it, represent the earth's surface. Using your ruler, make this line heavier, labeling it "Surface of the Earth." Near the left-hand edge of your paper lay your ruler at a right angle to this line and draw lines from it about five inches in length along both edges of your ruler. Color the space between them, above the "surface" line, and label it "A Vertical Sunbeam."

A short distance to the right of this, again lay your ruler across this "surface" line, placing it, by means of a protractor, at an angle of $66\frac{1}{2}°$. Draw lines along both edges of your ruler as before, and color in the space. Label it "A Sunbeam at $66\frac{1}{2}°$."

At the right of this, draw another sunbeam at an angle of $23\frac{1}{2}°$. Be sure that both sides of it come to the "surface" line. Color and properly label it.

Questions. 1. Since these sunbeams are of the same size, how does the amount of heat in one compare with the amount in the others?

2. Count the number of millimeters each beam covers in the line representing the earth's surface, and write the number in each.

3. Do these sunbeams spread their heat over the same amount of the earth's surface? Do they, therefore, heat the surface equally? Explain.

4. When the sun is over the equator, at what latitude does this vertical ray strike the earth? At what latitude the sunbeam of $66\frac{1}{2}°$? At what latitude the sunbeam of $23\frac{1}{2}°$?

5. Clearly state the reason why the average temperature of the earth's surface decreases gradually from the equator to the poles.

Determine the angle at which the sunbeam, at your locality, falls at noon on March 21 ($90°$ minus your latitude); on June 21 ($90° + 23\frac{1}{2}° -$ your latitude); and on Dec. 22 ($90° - 23\frac{1}{2}° -$ your latitude). On another sheet of cross-section paper, draw beams the width of your ruler, coming down at these angles to a line representing the earth's surface. Color each space, and in it write the proper date and the number of millimeters it covers on the line representing the earth's surface.

6. Why is it warmer in your locality in June than in January?

7. Explain why the heat from the sun on a clear day increases until noon and then decreases.

ELEMENTARY EXERCISE ON ISOTHERMS

Purpose. To map and to study the average annual distribution of temperature in the United States.

Directions. On a blank weather map of the United States (p. 193) clearly dot each city, and with neat figures write the given temperature on the north side of each dot. To map the temperature, lines should be drawn through all places having the even temperature of 40°, 50°, 60°, 70°.

To connect those at 40°, start the line from Chatham on the Atlantic coast, and draw it toward the nearest city having the same temperature — Parry Sound. Since Quebec is at 39° and Montreal at 41°, the line cannot go through either, but must pass halfway between them. From Parry Sound, the line goes to Marquette, passing south of Sault Ste. Marie, — one eleventh of the way toward Toledo, since they differ eleven degrees in temperature. Further west, Duluth is at 38° and La Crosse is at 46°. Since they differ eight degrees, this isotherm of 40° must pass two eighths of the way from Duluth to La Crosse. In this way construct the line west to Medicine Hat, curving the line to avoid any angles.

Then draw another line through cities having a temperature of 50°; another line through those at 60°; and another through places at 70°. Write the proper temperature at both ends of each line. Label the map: Isothermal Chart of the United States for the Year.

1. Which part of the United States is the coldest? Why?

2. How many degrees does the temperature change along the Pacific coast from Tacoma to San Diego? Along the Atlantic coast from Jupiter to Boston? Which varies more?

3. Explain the southward bend of the 50° isotherm in Colorado and New Mexico.

AVERAGE ANNUAL TEMPERATURE AND RAINFALL

Not corrected for elevation above the sea.

	Temp. (In Degrees)	Rainfall (In Inches)		Temp. (In Degrees)	Rainfall (In Inches)		Temp. (In Degrees)	Rainfall (In Inches)
Atlantic Region			**Lake Region**			**Rocky Mountains to Pacific**		
Chatham	40	42	Buffalo	48	38			
Montreal	41	41	Toledo	50	31	Phœnix	70	5
Quebec	39	42	Chicago	50	35	Yuma	72	3
Boston	50	43	Parry Sound	40	38	San Diego	60	11
Albany	48	38	Sault Ste. Marie	39	26	San Luis Obispo	60	17
New York	52	45	Marquette	40	32	Independence	60	6
Scranton	50	35	Duluth	38	30	San Francisco	56	24
Norfolk	60	52				Sacramento	60	20
Charlotte	60	52	**Gt. Lakes to Rocky Mountains**			Red Bluff	60	26
Atlanta	60	52				Eureka	55	46
Jacksonville	70	54	La Crosse	46	30	Reno	60	8
Jupiter	74	61	Moorhead	38	24	Winnemucca	50	8
Gulf Region			Huron	42	20	Salt Lake City	52	16
Tampa	72	55	Bismarck	40	18	Grand Junction	50	9
Mobile	68	62	Havre	40	14	Pocatello	48	15
New Orleans	70	61	Medicine Hat	40	14	Boise	50	14
Galveston	70	48	Denver	49	14	Spokane	47	20
Corpus Christi	70	29	Pueblo	51	12	Portland	53	47
Memphis	61	53	Omaha	50	28	Tacoma	50	45
			Davenport	50	34			
Ohio Valley			Oklahoma	60	30			
Chattanooga	60	53	Fort Smith	60	45			
Nashville	60	50	Santa Fe	50	14			
Cairo	59	43	El Paso	65	9			
Pittsburg	52	37	Amarillo	55	20			

DISTRIBUTION OF TEMPERATURE

Purpose. To study the distribution of temperature over the earth, and the influences that affect it.

Material. Isothermal maps of the world for January and July, in your text-book or atlas.

NOTE. The temperatures reported from places have been changed to show what they would be if all places were at sea level. Hence the influence of highlands is not shown.

A. 1. Find the two or three areas of greatest heat on each map. What is their average latitude in July? In January?

2. Why do the areas of greatest heat regularly change to these different latitudes every six months?

B. 3. What is the average July temperature at the middle of North America (at the crossing of the 40th parallel and the 100th meridian)?

4. What is the average July temperature at the middle of the ocean at this same latitude and the crossing of the 160th meridian west longitude?

5. Which, therefore, is the warmer in summer, the middle of the continent or of the ocean?

6. What is the average January temperature of each of these two places?

7. Which, therefore, is the cooler in winter?

8. Which, therefore, has a greater range (change) of temperature annually, an ocean or a continent?

C. 9. Which hemisphere, northern or southern, has the greater land area? Which the greater water area? In which do the isotherms most nearly coincide with the parallels of latitude? Explain why.

D. 10. In what direction do the prevailing winds blow across North America in the neighborhood of the 40th parallel? In July, at this latitude, what is the temperature at the shore of the Pacific? At the shore of the Atlantic? Although the oceans near these two places have about the same temperature, one place is much warmer than the other. Explain why. Which place is cooler in January? Explain why.

E. 11. At the same latitude, which place is warmer in both January and July, the ocean near England or near Labrador? The ocean near Norway or near Greenland? The Atlantic Ocean at the Tropic of Capricorn near South America, or near Africa?

12. Consult a map of ocean currents and explain why the temperatures vary so many degrees in each of the three cases just named.

F. 13. Review parts A, B, C, D, and E, and state five influences that affect the distribution of temperature over the earth.

Advanced Questions. 14. If the entire earth's surface were level land, how would the earth's temperatures be distributed?

15. What and where is the lowest temperature shown in these maps in January? In July? Why is one lower than the other?

16. Account for the crowded isotherms in Alaska in January.

17. In which month is the effect of the Gulf Stream and the North Atlantic Drift most apparent? Explain why.

18. What do these maps show to be the range of temperature at your home city? Compare the range at the western shore of Europe at the same latitude, and explain the difference.

SEASONAL RANGE OF TEMPERATURE. EFFECT OF LATITUDE

Purpose. To plot and to study the seasonal range of temperature at several places located at the ocean's shore but at different latitudes.

Directions. Let the heavy vertical lines of a sheet of cross-section paper represent the months of the year in order. At the top of the left vertical line write Jan.; at the top of the second heavy line write Feb. In this way, show the months given in the table below. Number the end of the top horizontal line 100°. Let one cm. space up and down represent 10°. Number the other horizontal lines to the bottom of the page.

Place a dot on the left vertical line to show the temperature recorded in table I (for Para) for Jan. In the same way dot the temperature for each of the other months in this table. Connect the dots with a curving line. This line is called the "temperature curve." In the same way, draw curves for tables II, III, IV, and V. Use lines of different colors if desired. Write the name of the city and its latitude at the end of each curve. Put all the lines on the same sheet.

TEMPERATURES, IN DEGREES F.

	PLACE	LAT.	JAN.	FEB.	MCH.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.
I.	Para, Brazil . .	0°	81	79	78	79	80	81	81	82	82	82	83	82	81
II.	Galveston, Tex. .	29° N.	52	58	63	70	77	82	84	82	77	71	62	56	52
III.	Portland, Me. . .	44° N.	21	22	30	41	52	63	68	66	60	48	37	26	21
IV.	Fort Conger . . .	82° N.	−38	−40	−28	−14	15	33	37	34	16	−9	−24	−28	−38
V.	Buenos Aires, Arg.	35° S.	76	75	72	67	60	55	51	52	56	60	66	71	76
VI.	Chicago, Ill. . .	42° N.	24	25	34	46	57	66	72	71	64	53	39	29	24

1. What month is warmest in curve II? In curve III? IV? Why is this the warmest month?

2. What month is the coldest in curve II? III? IV? Why?

3. What is the *amount* of seasonal range of temperature in curve I? II? III? IV?

4. What is the warmest month in curve V? Coldest month? Why is this curve different from the others?

5. Consult maps showing these cities and state whether the temperature ranges at these cities vary because they are at different distances from the sea, or at different altitudes above the sea.

What must be the reason for their difference?

6. Why is Fort Conger so excessively cold from October until April?

7. Why does Para have a smaller annual range than the other cities?

8. Plot the Chicago curve from the above data.

SEASONAL RANGE OF TEMPERATURE. EFFECT OF LAND AND SEA

Purpose. To plot and to study the seasonal range of temperature at two places which are at *equal* distances from the equator, and at equal altitudes: one place being in the interior of a continent (St. Louis, Mo.); the other place being on an island in the ocean (Ponta Delgada, Azores Is.).

Directions. Mark the months along the top margin of a sheet of cross-section paper, and the temperatures along the side margin just as in the preceding exercise. Draw the temperature curves for both places on the same sheet.

TEMPERATURES, IN DEGREES F.

		JAN.	FEB.	MCH.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.
I.	St. Louis, Mo. . . .	30	35	42	55	65	75	84	76	69	57	44	34	30
II.	Ponta Delgada . . .	66	65	66	68	70	72	74	76	74	72	69	67	66

1. State the latitude and describe the general location of each of these places.

2. What is the amount of seasonal range (change) of temperature in curve I? In curve II?

3. Which of the two places shows the smaller range? The greater range?

4. Do these places differ because they are at different latitudes? At different altitudes?

5. What, then, must be the reason?

DAILY RANGE OF TEMPERATURE

Purpose. To plot and to study the daily changes of temperature in summer and in winter: (*a*) at a place in the interior of a continent (St. Louis), and (*b*) at a place on an island in the ocean (Key West).

Directions. Write 12 Midnight at the top of the left vertical line of a sheet of cross-section paper. Let each of the centimeter spaces from left to right represent two hours. Mark the proper hour of A.M. or P.M. at the top of each vertical line as far as the next midnight line. Using a ruler, make the noon and midnight lines heavier, and label each.

Number the end of the top horizontal line 100° F. Let one centimeter space up and down represent 5°. Number the other horizontal lines to the bottom of the page.

Place a dot on the left midnight line at the temperature recorded below in table I. In the same way dot the temperature for each of the other hours in this table. Connect these dots with a curving line. This line is called the "temperature curve."

In the same manner, on the same sheet, plot the temperatures shown in tables II, III, and IV, and draw the curves, numbering the curves the same as the table.

TEMPERATURES, IN DEGREES F.

		Midnight	2	4	6	8	10	Noon	2	4	6	8	10	Midnight
I.	Key West (summer)	79	78	77	79	83	86	88	90	90	86	83	80	79
II.	Key West (winter)	68	66	65	64	67	73	77	78	77	75	73	70	68
III.	St. Louis (summer)	76	72	69	70	74	81	91	97	97	85	81	78	76
IV.	St. Louis (winter)	11	10	7	5	6	12	19	32	25	20	16	13	11

1. State the latitude and general location of each of these places.

2. What hour is the warmest in curve I? In curve II? III? IV?

3. Why is this the warmest part of the day?

4. What is the coldest hour in curve I? II? III? IV?

5. Why is this the coldest part of the day?

6. What is the amount of daily temperature change (range) in curve I? II? III? IV?

7. Which of these two places shows the greater range in summer? In winter?

8. State two reasons for this.

Advanced Questions. 9. At each place, does the temperature begin to increase at an earlier hour in summer or in winter?

From the almanacs find the time of sunrise in summer (July 1) at each place.

10. At which should the temperature begin to increase earlier?

11. How much earlier?

12. In the same way compare them in winter (Jan. 1).

TERRESTRIAL OR PLANETARY WIND BELTS

Purpose. To study the location and characteristics of the wind belts of the earth.

Material. Two pilot charts of the North Atlantic Ocean — a summer month and a winter month. (These charts may be obtained from the Hydrographic Office, Washington, D.C.)

You are to study the winds in the middle of the ocean, away from the influence of the land, and record the facts you learn in the blank spaces of the table below. The equatorial calms lie in the southern part of the chart, bounded by two dotted lines named "northern limit of the southeast trades" and "southern limit of the northeast trades." The trade belt extends from the equatorial calms to a line marked "northern limit of the northeast trades." The tropical calm belt extends from the northern border of the trades nearly to the Azores Islands. The prevailing westerlies extend from the tropical calms north beyond the limits of the chart. In recording the latitude of each belt, give the north and the south boundary in the middle of the ocean — summer month in one line, winter month in the other.

The character of the winds in each rectangle bounded by the light black lines (either continuous or dashed) is indicated by the diagram called a "wind rose," in blue at the center of the rectangle. The figure within the circle is the per cent of time calm. In filling the blank of the table, give the highest, the lowest, and the average of several rectangles near the middle of the ocean, in each wind belt.

The directions of the winds are indicated by the blue lines (arrows) drawn to the circle. The wind comes in the direction of the arrow toward the center. Give as the prevailing direction that indicated by the longest arrow, or if there are several long arrows, give an intermediate direction between them. Give the direction *from* which the wind comes. If no direction seems to prevail, write "variable."

The length of the arrow shows the comparative length of time the wind blows from the direction indicated. Under the head "constancy of direction" in the table use adjectives, such as "very constant," "moderately constant," "very irregular," etc., to describe the steadiness of direction of the wind.

The velocity of the wind is shown by the "feathers" at the end of the arrow. The numbers of feathers correspond with the numbers of Beaufort's Scale here given. Record for each belt the maximum velocity indicated and the most common velocity. This maximum is not the strongest wind experienced in the belt, but the month's average from the direction indicated.

BEAUFORT'S SCALE

Number of Feathers	Kind of Wind	Miles per Hour	Number of Feathers	Kind of Wind	Miles per Hour
0	Calm	0– 3	7	Moderate Gale	34–40
1	Light Air	3– 8	8	Fresh Gale	40–48
2	Light Breeze	8–13	9	Strong Gale	48–56
3	Gentle Breeze	13–18	10	Whole Gale	56–65
4	Moderate Breeze	18–23	11	Storm	65–75
5	Fresh Breeze	23–28	12	Hurricane	75–90 and over
6	Strong Breeze	28–34			

CHARACTERISTICS OF WIND BELTS

	Equatorial Calms or Doldrums	N. E. Trades	Tropical Calms, Horse Latitudes	Prevailing Westerlies
Latitude { Summer				
Latitude { Winter				
Per cent of time calm				
Prevailing direction of wind .				
Constancy of direction . . .				
Velocity { Maximum				
Velocity { Average				

Advanced Questions. 1. Which belts are narrow?

2. Which are wide?

3. In which belts are the winds noticeably variable?

4. In which are they more constant?

5. In which is a relatively large per cent of the time calm?

6. In which is there little time calm?

7. Explain from the direction of air movement why these things are so.

8. How does the summer month differ from the winter month in velocity of winds, directions, etc.?

9. On a blank Mercator's map (from near end of this book) plot the wind belts. Use arrows to indicate prevailing directions,—longer for the more constant winds; use small circles to mark the equatorial calms, and small crosses for the tropical calms.

FERREL'S LAW

Object. To learn how the rotation of the earth affects the direction of winds and currents.

Material. A small globe, a pin, and a string.

Directions. Put a pin through a knot at one end of a string two feet or more long. Prick no holes in the globe, but find several holes already made along longitude 180°. Put a pin in a hole in the north temperate zone. Extend the string straight north (globe direction) in a plane horizontal to the surface of the globe at the place it touches, and hold it at the end. Turn the globe slowly to the east (counterclockwise) through less than $\frac{1}{8}$ of a rotation, holding the end of the string all the time in the same place. The wind is supposed to start at the pin and blow toward your hand, to the north.

1. The earth's rotation deflects the wind to the east or the west of a north direction?

To the right, or to the left, as you stand facing north?

Extend the string east from the pin (at right angles to the meridian, horizontal). Rotate the globe slightly to the east, being careful to keep the string taut by pulling straight on it.

2. The west wind, from the pin toward the hand, is deflected to the north or to the south of east?

To the right, or to the left, of one facing east?

For the north wind, extend the string south from the pin. Rotate the globe toward the east.

3. Does the rotation of the earth deflect this wind to the east, or to the west, of a south direction?

To the right, or to the left, of one going with the wind?

Extend the string west from the pin horizontally at right angles to the meridian to represent an east wind.

4. Does the earth's rotation deflect this wind to the north, or to the south, of a west direction?

To the right, or to the left?

5. Try the same experiments at other latitudes north of the equator. A wind in the northern hemisphere, blowing in any direction, is deflected by the earth's rotation to which hand?

Put the pin in a hole in a south temperate latitude, and slightly rotate the globe toward the east with the string extended toward the north, east, south, and west. Note the direction of deflection. Try other southern latitudes.

6. A wind in the southern hemisphere, blowing in any direction, is deflected by the earth's rotation to which hand?

Repeat the experiment with the pin at the equator.

7. What result do you obtain?

Repeat again with the pin near a pole.

8. Is the deflection greater near the equator, or far from it?

Fill the blanks in this statement of Ferrel's Law.

Bodies moving freely (wind, water, cannon ball) in any horizontal direction are deflected by the earth's rotation to the ________ hand in the northern hemisphere, and to the ________ hand in the southern hemisphere. At the equator the deflection is ________ (much or little); the farther a place is from the equator the ________ (greater or less) is the deflection.

WEATHER MAPS

Purpose. To represent, on a map, the weather conditions on a given date.

OBSERVATIONS TAKEN FEB. 10, 1907, AT 8 A.M., 75TH MERIDIAN TIME

	Barom.	Therm.	Wind Direction	Precipitation		Barom.	Therm.	Wind Direction	Precipitation
Atlantic Region					Miss. River to the				
Father Point	29.8	15	S.	S.	Rocky Mts.				
Halifax	30.0	20	S.E.	S.	Moorhead	30.2	18	N.W.	
Quebec	29.7	20	S.	S.	Williston	30.4	12	W.	
Montreal	29.6	22	S.	S.	Prince Albert	30.2	12	W.	
Rockliffe	29.4	26	E.	S.	Edmouton	30.2	20	W.	
Boston	29.9	20	S.	S.	Medicine Hat	30.4	20	W.	
Albany	29.8	20	S.	S.	Helena	30.6	24	W.	
Philadelphia	29.9	30	S.	S.	Lander	30.6	22	N.W.	
Norfolk	30.0	40	S.		Valentine	30.4	20	N.W.	
Charleston	30.1	40	W.		Des Moines	30.2	32	N.W.	
Jupiter	30.1	54	N.		Wichita	30.4	30	N.	
					Pueblo	30.5	25	N.	
Gulf to the					Amarillo	30.5	30	N.	
Great Lakes					Abilene	30.3	40	N.	
Tampa	30.1	46	N.						
Mobile	30.1	48	N.						
Galveston	30.1	50	N.W.						
Memphis	30.2	44	S.W.						
Knoxville	30.0	40	S.W.		Rocky Mts. to the				
Cairo	30.2	36	N.W.		Pacific Ocean				
Milwaukee	29.8	30	W.		El Paso	30.2	40	N.E.	
Columbus	29.9	35	S.W.	R.	Santa Fe	30.4	30	N.E.	
Cleveland	29.6	33	S.W.	R.	Phœnix	30.1	45	E.	
Pittsburg	29.8	34	S.W.	R.	Yuma	30.1	50	N.E.	
Oswego	29.6	30	S.	S.	Pocatello	30.6	30	S.	
Saugeen	29.4	30	S.W.	S.	Baker City	30.4	31	S.	
Sault Ste. Marie	29.6	25	N.	S.	Roseburg	30.2	50	S.E.	
Port Arthur	29.8	20	N.W.		Portland	30.1	40	S.E.	
Duluth	30.0	20	N.W.		Kamloops	30.4	30	S.W.	

Directions. A. On a blank United States weather map, plainly dot each city named in the list. With neat figures, mark the given temperature (see the third column of the table) on the north side of each dot. Find the cities marked 20°, and, beginning at the Atlantic coast, draw a curving line through all of them. Keep this isothermal line the proper distance from cities having temperatures slightly above or below 20° in the manner explained on page 142. With another line, connect the cities at 30°; then those at 40°; and those at 50°. Mark the temperature at both ends of each of these lines.

B. On another blank weather map, clearly dot the same cities. On the north side of each dot, neatly dot the barometer reading given in the table. Find the two cities marked 29.4, and draw a free-hand circle connecting them. Then draw a nearly complete circle through the places marked 29.6. Using a separate line for each group, connect places having the following pressures, in order: — 29.8, 30.0, 30.2, 30.4, 30.6. Print LOW in the circle of 29.4, and HIGH in the circle 30.6.

Through each city draw an arrow one half inch long, flying with the wind, remembering that the name of the wind shows the direction *from* which it comes.

At the cities where snow or rain is reported, print the proper letter S. or R. on the arrow. Slightly shade the entire area where snow or rain seems to be falling.

C. On this second map (B), copy the isotherms drawn on the first map (A), using a dotted line or a colored line. Label this map "Weather Map for Feb. 10, 1907."

D. 1. Compare the winds in the general area of HIGH pressure (above 30.0 inches) with those in the general LOW area, and describe the air movement in each.

2. Which area is the colder? Does the air seem to be moving towards the center of this area or away from it? Then is the air at this center sinking or rising?

3. In which of these areas is there a fall of snow and rain? Does this indicate rising or sinking air?

4. Why does one part of this area have rain and the other have snow?

5. From which of these areas does the air move to the other? Why does it?

E. In the manner described in A and B, draw the weather map for Feb. 11, from the data below.

6. Describe the air movement around the LOW and around the HIGH.

7. How do these directions compare with those of the previous day?

8. Compare the temperature and snowfall of the LOW with those of the previous day.

9. In what direction has the LOW moved from the previous day? How far (use scale of miles)? Which way and how far has the HIGH moved?

10. Which of these areas brings the cold wave?

OBSERVATIONS TAKEN FEB. 11, 1907, AT 8 A.M., 75TH MERIDIAN TIME

Feb. 11, 1907	Barom.	Therm.	Wind Direction	Snow or Rain
Atlantic Region				
Father Point	29.4	30	S.E.	S.
Halifax	29.6	40	S.W.	R.
Quebec	29.4	20	W.	S.
Montreal	29.6	10	W.	S.
Rockliffe	29.8	−10	W.	S.
Boston	29.6	40	W.	S.
Albany	29.7	20	W.	S.
Philadelphia	29.9	30	N.W.	
Norfolk	29.9	40	N.W.	
Charleston	30.0	50	N.W.	
Jupiter	30.1	62	N.	
Gulf to the Great Lakes				
Tampa	30.1	60	N.	
Mobile	30.2	50	N.W.	
Galveston	30.3	50	N.	
Memphis	30.3	40	N.	
Knoxville	30.2	30	N.W.	
Cairo	30.3	35	N.W.	
Milwaukee	30.3	10	W.	
Columbus	30.1	25	N.W.	
Cleveland	30.0	20	W.	S.
Pittsburg	30.0	20	W.	
Oswego	29.8	14	N.W.	S.
Saugeen	30.0	0	N.W.	S.
Sault Ste. Marie	30.2	−10	W.	S.
Port Arthur	30.2	−10	S.	
Duluth	30.2	0	S.E.	
Miss. River to the Rocky Mts.				
Moorhead	30.1	10	S.E.	
Williston	30.0	20	S.W.	
Prince Albert	29.8	30	S.	S.
Edmonton	29.8	32	N.	S.
Medicine Hat	30.0	30	S.W.	S.
Helena	30.4	20	W.	
Lander	30.6	20	S.W.	
Valentine	30.2	20	W.	
Des Moines	30.3	30	S.	
Wichita	30.4	30	W.	
Pueblo	30.6	20	N.W.	
Amarillo	30.5	30	N.W.	
Abilene	30.5	40	N.W.	
Rocky Mts. to the Pacific Ocean				
El Paso	30.4	40	E.	
Santa Fe	30.5	30	N.E.	
Phœnix	30.2	50	N.E.	
Yuma	30.1	55	N.E.	
Pocatello	30.4	25	S.E.	
Baker City	30.3	30	S.E.	
Roseburg	30.2	40	E.	
Portland	30.2	40	S.E.	
Kamloops	30.2	35	W.	

WEATHER RECORD

Date	Barometric Pressure	Temperature	Relative Humidity	Kinds of Clouds	Rain or Snow	Amount	Direction of Wind	Position of Storm Center

WEATHER RECORD

Date	Barometric Pressure	Temperature	Relative Humidity	Kinds of Clouds	Rain or Snow	Amount	Direction of Wind	Position of Storm Center

THE TEMPERATE LATITUDE CYCLONE

Purpose. To study the cyclonic storms of the United States, which cause the irregular changes of weather.

Material. A group of daily United States weather maps for two weeks or a month, bound together; a sheet of tracing paper.

The weather map is made from data telegraphed from all weather stations to central stations — Washington, Chicago, etc. — at the same hour in the morning — 8 o'clock Eastern time, 7 o'clock Central time, 6 o'clock Mountain time, 5 o'clock Pacific time. On the map the isotherms are dotted lines (red on the maps printed at Washington); the isobars are continuous lines; the areas marked LOW are the storm or cyclone centers; the areas marked HIGH are the anticyclones. For further explanation see the lower left corner of the map.

A. Size of the Temperate Latitude Cyclone. By means of the scale of miles given on the map measure the width of several cyclonic storms, including in each storm all the isobars that encircle it.

1. State the maximum, the minimum, and the average width.

If the storm is oval in shape, give the direction of the longest diameter in each of several storms.

B. Direction of Wind in the Cyclone and the Anticyclone. The winds represented at a city any day may be influenced by local conditions and so changed from their typical direction. That you may get at once a view of the winds of several storms, and in this way overcome the influences of local conditions, follow these directions for the use of tracing paper.

At the top of the sheet of tracing paper write this heading: "Tracings from weather maps." Draw a vertical line dividing the page into two equal columns. Draw two lines across, dividing each column into three equal parts. At the top of the first part, on the middle line write the word "Wind," at the top of the second part the word "Temperature," at the top of the third part the word "Moisture." In the middle of each of the three left-hand sections write the word "LOW"; in the middle of each right-hand section write the word "HIGH." Prepare a sheet of writing paper in the same way, except the general heading, which should be "Generalized Weather Conditions."

Place the word LOW of the wind section of the tracing paper over the center of a well-defined storm (LOW) on the weather map (a storm having several isobars encircling the center), the top of your paper to the north of the map. Trace all the arrows covered by this section of your tracing paper. Find on any day another well-defined storm; place the same LOW of your paper over its center, top of your paper to the north, and trace the arrows here covered.

Repeat the process till the arrows of your tracing paper clearly show on each side of the LOW a well-marked prevailing direction of the wind. In the corresponding section of your writing paper draw six or eight arrows, one each side of the LOW, each representing the prevailing direction of the winds on its side of the storm as you observe it on your tracing paper.

2. Do the winds blow toward, or from, the LOW? To which hand are they deflected?

Is this according to Ferrel's Law?

Place the HIGH of the wind section of your tracing paper over a well-defined anticyclone (HIGH) and trace the arrows. When you have traced the arrows of a sufficient number of anticyclones, draw an arrow on each side of the word HIGH on the writing paper to indicate the directions of the wind around HIGH.

3. Do the winds blow toward, or from, the HIGH? To which hand are they deflected?

Does this accord with Ferrel's Law?

C. Temperatures of the Cyclones and the Anticyclones. The temperature of the storm can be told by means of isothermal lines in or near the center. Note the temperatures of all the LOWS in the

central part of the United States during the few weeks represented by your maps; get the average. Note the temperatures of the HIGHS in the same region, during the same time, and get the average.

Place the LOW of the second section of your tracing paper over a well-defined storm center and trace the isotherms covered. Repeat with other storms till your paper shows a prevailing form of isothermal lines in or near the storm. Draw a single line through the corresponding LOW of your writing paper to show this prevailing form. Mark at the ends of this line the average temperature of these LOWS. Trace and record the isotherms of the HIGH in the same way.

4. Which has the higher temperature, the cyclone or the anticyclone?

Is the east side of the cyclone warmer or cooler than the west?

D. Moisture in the Cyclone and the Anticyclone. Place the LOW of the third section of your tracing paper over the center of a well-defined storm, and trace the circles indicating moisture conditions, shading those that are shaded and also those marked *R* and *S*. Repeat for several storms. Shade the corresponding section of the writing paper to express the degree of cloudiness in different parts of the LOW. Study the HIGH in the same manner.

5. Is the LOW generally cloudy or clear?

Is the HIGH generally cloudy or clear?

On which side of the storm center is the cloudiness the heaviest?

E. Path of the Storm. On several consecutive weather maps find the same well-defined storm. On a blank weather map write the day of the month on which the storm is first noted, at the city nearest the storm center. On the same blank map write the next day of the month at the city nearest the storm center on the second day the storm is observed; continue as long as the storm can be traced. Draw a line of arrows connecting these date figures; it will indicate the path of the storm. On the same blank map trace the movements of several storms.

6. What is the general direction of movement of the storms?

What is the greatest number of miles a storm moves in one day?

What is the least number?

What is the average of several days of ordinary movement?

Advanced Questions. 7. Study the paths of the anticyclones as you have those of the cyclones.

8. Trace the paths of many storms, till you can observe several routes across the United States commonly taken by the storms. Describe each route. Compare summer routes with winter routes.

RAINFALL IN THE UNITED STATES

Purpose. To map and to study the average annual rainfall within the United States.

Directions. On a blank weather map of the United States, clearly dot each city named in the table on page 142.

With neat figures, mark the number of inches of rainfall (given in that table) on the north side of each dot. Draw a line through the places in central United States which have 20 inches of rainfall (this will lie in the neighborhood of the 100th meridian). Keep the line the proper distance from the cities having other amounts (in the manner described on page 142). Then in order eastward, connect places having a rainfall of 30 inches, of 40 inches, of 50 inches, and of 60 inches, respectively. Then west of the 100th meridian, connect places having 10 inches, 20 inches, 30 inches, and 40 inches of rainfall. Label the map "Average Annual Rainfall of the United States, in Inches."

Color lightly the area between 0 inches and 10 inches, — reddish yellow;
" " " " 10 inches and 20 inches, — yellow;
" " " " 20 inches and 40 inches, — light green;
" " " " 40 inches and 60 inches, — dark green;
" " " above 60 inches, — black.

1. Explain the rainfall of the following areas, stating whether it is mainly due to its nearness to or distance from the sea, the direction of the wind belt, mountains aiding or hindering, cyclonic storms, etc.

(*a*) Western Oregon and Washington.

(*b*) Southern Arizona.

(*c*) Northern Nevada and Utah.

(*d*) The Great Plains.

(*e*) The regular increase from the Great Plains to the Atlantic.

(*f*) Southeastern Florida.

2. Where must there be small areas of heavy rainfall not indicated by the reports from the cities in the table?

3. Compare your map with the one on page 8 and be prepared for an oral explanation of minor differences.

SEASONAL DISTRIBUTION OF RAINFALL

Purpose. To plot and to study the amount and distribution of rainfall throughout the year at different latitudes.

Directions. By heavy horizontal lines, divide a sheet of cross-section paper into three equal parts (each 8 by 18 cm.). Mark the base line of each of the three parts, 0. Let one centimeter vertically represent one inch of depth of rainfall, each part of the paper thus representing eight inches. Beginning with each 0 line, number the eight inches of each section on the side margins.

Let the left-hand vertical space, one centimeter wide, from the top to the bottom of the paper, represent January. Let the next vertical space represent February, etc., as given in the table below. Write the name of each month at the top of the proper space.

Let the upper third of the sheet represent San Francisco. Across the space for January draw a horizontal line to show the exact depth of rainfall given in the table below, and lightly shade the space between this line and the base line. Repeat this for each month. In the same manner draw the rainfall chart for Quito in the middle section, and for Valparaiso in the lower. Write the name of the proper city in each section.

RAINFALL, IN INCHES

PLACE	LAT.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	TOTAL FOR YEAR
San Francisco, Cai.		5.6	4.1	3.5	2.5	1.2	0.3	0.1	0.1	0.5	1.4	3.3	5.7	5.6	
Quito, Ecuador		3.3	4.0	4.8	7.2	5.2	1.3	1.2	2.2	2.8	4.0	4.2	3.6	3.3	
Valparaiso, Chile		0.1	0.2	1.0	1.6	3.0	4.1	2.9	1.8	0.8	0.5	0.3	0.1	0.1	

Questions. 1. What months mark the height of the two rainy seasons at Quito?

What months mark the dry seasons there?

2. What wind belt near the equator causes these heavy rains? Why does it?

3. Why do not the equatorial calms affect Quito every month?

4. At what two dates is the sun directly over Quito?

Dot these dates on your chart, and neatly label them "sun overhead."

5. Does your chart show that the equatorial calms precede or lag behind the sun in its north and south movement?

6. In which months do the winds bring the most rainfall from the ocean to San Francisco? In which direction must these winds blow? To what wind belt must these winds belong?

7. Which month shows the least rainfall in San Francisco? Which way must the wind be blowing? To what wind belt must these winds belong?

8. What wind belt does your chart show must affect Valparaiso in July? In January?

9. Why does Valparaiso have its heavy rains while San Francisco is having its dry season?

SEASONAL DISTRIBUTION OF RAINFALL (Advanced)

Select some of the cities given in the following table, and chart their rainfall as in the preceding exercise or by means of curves. To draw the curves, place the names of the months in order at the top of the heavy vertical lines. Let each centimeter vertically represent one inch. Label the lowest horizontal line zero, then write the proper numbers along the side margins to the top of the page. Place a dot on each vertical line at the proper place to show the depth of rainfall for that month, and connect these dots by a curving line. Several curves may be placed on the same page. State the city and its latitude at the end of the curve. If the curves cross each other, use different colors.

RAINFALL, IN INCHES

PLACE	LAT.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	TOTAL FOR 12 MONTHS
Rio Janeiro, Brazil . . .		5.4	5.7	5.9	5.4	4.5	1.5	1.3	2.8	3.3	3.9	4.5	5.1	5.4	
Libreville, French Kongo .		7.5	9.0	15.0	10.0	8.7	0.9	0.5	1.2	8.1	19.4	19.1	7.8	7.5	
Cape Town, Cape Colony .		.07	0.8	1.0	1.3	4.0	4.6	3.6	3.4	2.2	1.8	1.1	0.9	0.7	
Calicut, India		1.0	0.8	2.2	4.8	12.2	30.0	22.0	14.0	13.0	12.2	5.4	1.8	1.0	
London, England		2.0	1.6	1.4	1.8	1.9	2.0	2.5	2.4	2.4	2.5	2.1	2.1	2.0	
Yuma, Arizona		0.51	0.51	0.26	0.07	0.04	0.01	0.14	0.35	0.14	0.28	0.29	0.46	0.51	
Tatoosh Island, Puget Sound		13.6	9.6	9.0	6.8	4.6	3.8	1.9	2.5	5.6	7.4	13.5	15.3	13.6	
Chicago, Illinois		2.0	2.3	2.6	2.7	3.5	3.6	3.7	2.9	3.0	2.5	2.4	2.1	2.0	

Properly fill out this table about each city you chart.

CITY	LAT.	ON A NORTH, SOUTH, EAST, OR WEST COAST	WIND BELT DURING RAINY SEASON	DIRECTION OF AIR MOVEMENT	WIND BELT DURING DRY SEASON	DIRECTION OF AIR MOVEMENT	ANY SPECIAL CAUSES, AS MOUNTAINS, PLAINS, WARM OCEAN CURRENTS, ETC.

MAGNETISM. THE COMPASS

Purpose. To observe magnetic attraction, polarity, and its application to the compass.

Material. Two bar magnets, iron filings, or magnetic iron ore in small grains, pieces of thread (some very fine), and needles.

A. Put a small heap (one fourth teaspoonful) of iron filings or grains of magnetic iron ore on a sheet of paper. Bring one end of a bar magnet within one half inch of the grains of iron. Tap the paper gently to aid the movement of the grains.

1. Describe (sketch if you can) the way in which the grains arrange themselves.

2. Bring the other end of the magnet near the grains. What is the effect?

3. Lay the magnet under the paper and sprinkle the grains over the paper; tap a few times very gently. Describe (sketch) the arrangement of the grains.

B. Suspend the magnet in a sling (a paper loop at the end of a thread). Very slowly bring the S end of another magnet near and *at the side* of the S end of the suspended magnet.

4. What motion of the suspended magnet follows?

Does this mean attraction or repulsion?

Bring the N end of the second magnet near the S end of the suspended magnet.

5. What motion of the suspended magnet follows?

Does this mean attraction or repulsion?

6. Bring the two N ends near each other; what motion follows?

Is there attraction or repulsion?

7. Fill the blanks in the following statement by the correct word — *attract* or *repel.*

Like poles of a magnet each other; unlike poles each other.

C. Magnetize a needle by laying it lengthwise on a magnet and sliding it back and forth. Suspend the magnetized needle over the end of your desk, the needle horizontal, at the end of a long, very fine thread, no magnet near. Turn it back and forth, then let it come to rest.

Repeat this three or four times. If your experiment is successful, the needle will repeatedly take the same position.

8. Toward what points of the compass do the ends lie?

Why do you think the needle does not take this position by chance?

Slowly bring the N end of a magnet near the north-pointing end of the needle.

9. Is there attraction or repulsion shown?

Does the N or the S end of the needle point north?

10. Is this needle a compass?

11. Test the magnet by carefully suspending it on a thread as long and as fine as is convenient, and holding it till it comes to rest. Try several times. Is the large suspended magnet a compass?

SECTION OF OCEAN BORDER. CONTINENTAL SHELF

Purpose. To show the widths of the continental shelf, the depths of water, and the slopes of the bottom.

Directions. Write "sea level" on the second line from the top of a sheet of cross-section paper. Let each centimeter along this line represent 10 miles, and each centimeter down from this line represent 100 fathoms.

1. This gives how much vertical exaggeration?

Below the sea-level line make a series of small dots according to the data given below. *E.g.*, for Atlantic City, one centimeter from the starting point (10 miles) make a dot a little more than half a small square (12 fathoms) below sea level. Two centimeters (20 miles) from the starting point, make a dot $\frac{3}{4}$ of a small square below sea level (15 fathoms), at three centimeters (30 miles) make a dot $1\frac{1}{4}$ small squares (25 fathoms) below sea level, and so on.

A line connecting the dots represents the continental shelf, and the beginning of the slope down to the deep sea bottom.

In the same manner draw other sections to the same sea-level line, using a different kind of line — dots, dashes, or colors for each section; or draw each section to a separate sea-level line.

East from Atlantic City, N.J.

Distance from Shore, Miles	Depth of Water, Fathoms	Distance from Shore, Miles	Depth of Water, Fathoms	Distance from Shore, Miles	Depth of Water, Fathoms
10	12	50	30	85	500
20	15	60	40	90	1000
30	25	70	50	100	1300
40	20	75	100		

2. At about what depth does the steep slope of the front of continental shelf begin?

3. About how many miles wide is the shelf at Atlantic City?

4. Does the bottom of the water slope continuously down from the shore outward?

From Jupiter Inlet, Florida, east to Bahama Islands.

Distance from Shore, Miles	Depth of Water, Fathoms	Distance from Shore, Miles	Depth of Water, Fathoms	Distance from Shore, Miles	Depth of Water, Fathoms
2	6	30	400	55	280
4	16	35	430	57	100
10	100	40	420	58	0
20	250	50	340		

The Gulf Stream flows north through this strait, most swiftly where the water is deepest.

5. Which side of the strait has the steeper slope?

6. Is the shallow water bordering the shore a broader, or a narrower, strip than at Atlantic City?

From South Pass (Mouth of Mississippi River) Southeast

Distance from Shore, Miles	Depth of Water, Fathoms	Distance from Shore, Miles	Depth of Water, Fathoms	Distance from Shore, Miles	Depth of Water, Fathoms
2	20	20	300	40	700
4	45	25	400	50	950
10	85	30	550		
15	190	35	620		

7. The delta at the mouth of the Mississippi is building on this shelf. It has reached within how many miles of the border of the shelf?

For the section from Portland, the sea-level line must run lengthwise of the paper.

From Portland, Me., Southeast

Distance from Shore, Miles	Depth of Water, Fathoms	Distance from Shore, Miles	Depth of Water, Fathoms	Distance from Shore, Miles	Depth of Water, Fathoms
2	20	90	130	170	25
6	50	100	110	180	30
10	75	110	90	190	35
20	100	120	100	200	45
30	50	130	105	210	55
40	70	140	20	220	70
50	90	142	10	225	100
60	50	146	20	230	500
70	100	150	20	235	1000
80	110	160	20	240	1300

8. The shallow strip beginning 140 miles from shore is probably a glacial moraine. It is valuable as a fishing bank. How wide is this bank?

9. How many miles wide is the shelf at Portland?

10. Is the bottom more, or less, uneven than in the Atlantic City section?

SECTION OF THE NORTH ATLANTIC OCEAN

Purpose. To draw a profile from the Blue Ridge Mountains, Virginia, to Monte Junto, Portugal, showing the slopes of the land and the depths of the ocean, at latitude 39°N.

Directions. On a sheet of cross-section paper, draw a line parallel to the binding margin of the paper and three centimeters from the margin, and label it "sea level." Using a horizontal scale of one centimeter for 200 miles, and a vertical scale of one centimeter for 1000 fathoms (= 6000 feet), make a series of dots according to the following data and draw line connecting the dots. Shade green or blue the space between sea level and the bottom of the ocean.

Distance from West End	Land Surface or Ocean Bottom
0 miles, Blue Ridge	3000 feet altitude
10 miles, foot of mountain	1000 feet altitude
200 miles, shore	0 feet altitude
290 miles, shelf	100 fathoms deep
320 miles,	1000 fathoms deep
540 miles,	2000 fathoms deep
1000 miles,	3000 fathoms deep
1640 miles,	3000 fathoms deep
2260 miles,	2000 fathoms deep
2460 miles,	1000 fathoms deep
2660 miles, edge of ridge	500 fathoms deep
2685 miles, shore Azores Islands	0 feet altitude
2700 miles, edge of ridge	500 fathoms deep
2800 miles,	1000 fathoms deep
2940 miles,	2000 fathoms deep
3560 miles,	2000 fathoms deep
3610 miles,	500 fathoms deep
3640 miles, shore	0 feet altitude
3665 miles, Monte Junto	2200 feet altitude

About 1200 miles from the west side of the ocean, write at the proper places for the depths here given, the temperatures of the water. At the surface 70 degrees, at a depth of 200 fathoms 39 degrees, at a depth of 1000 fathoms 38 degrees, at the bottom 35 degrees.

Questions. 1. How much is the vertical exaggeration of the section?

2. About how many miles wide is the Atlantic Ocean at latitude 39° N? How deep? Where is the deeper part?

3. How broad is the ridge on which the Azores Islands stand?

4. Which side of the ocean at this latitude has the broader continental shelf? Which has the broader coastal plain?

5. Do you think the seashore, or the edge of the continental shelf, should be taken as the border of the continent? Give a reason.

6. Does the temperature change more rapidly near the surface, or near the bottom, of the ocean?

TIDES IN THE OCEAN

Purpose. To study the tidal changes of water level.

According to the following directions make a graph to represent the upward and downward movements of the surface of the sea at Eastport, Maine, from Sept. 17 to Sept. 28, 1899.

On a sheet of cross-section paper, along the binding border, write numbers on heavy lines to represent the days of the month given above; — thus, one centimeter from the left write 17, three centimeters from the left 18, five centimeters 19, etc., two centimeters representing one day, and the number being written on the noon line. Notice that 6 o'clock will come in the middle of the centimeter space; estimate the positions of the other hours. Four centimeters from the top draw a line across the sheet and label it "mean (average) sea level." At the ends label the heavy lines above mean sea level 5, 10, 15, and the heavy lines below – 5, – 10, – 15, each centimeter representing five feet.

Make a dot in the proper place for 2 : 21 A.M. (about one small square from the left) and – 10.3 feet, — the first ebb tide Sept. 17. Make another dot for 8 : 28 A.M. (more than three small squares from the left) and 9.8 feet, — the first flood tide for Sept. 17. Connect these dots by a straight line. Make another dot for 2 : 46 P.M. and – 10.3 feet, — the second ebb tide for Sept. 17. Draw a line from this dot to the flood tide dot preceding. Continue across the sheet according to the data here given:

Day, Sept.	Hour	Height, Feet	Day, Sept.	Hour	Height, Feet	Day, Sept.	Hour	Height, Feet	Day, Sept.	Hour	Height, Feet
17.	2 : 21 A.M.	– 10.3	20.	4 : 52 A.M.	– 11.8	23.	12 : 56 A.M.	10.4	26.	3 : 30 A.M.	7.2
	8 : 28 A.M.	9.8		10 : 58 A.M.	11.9		7 : 12 A.M.	– 10.2		9 : 49 A.M.	– 7.1
	2 : 46 P.M.	– 10.3		5 : 17 P.M.	– 12.0		1 : 16 P.M.	10.8		3 : 52 P.M.	7.7
	8 : 52 P.M.	10.8		11 : 24 P.M.	11.6		7 : 43 P.M.	– 10.7		10 : 35 P.M.	– 7.7
18.	3 : 15 A.M.	– 11.0	21.	5 : 39 A.M.	– 11.6	24.	1 : 44 A.M.	9.4	27.	4 : 29 A.M.	6.4
	9 : 21 A.M.	10.8		11 : 45 A.M.	10.9		8 : 00 A.M.	– 9.2		10 : 50 A.M.	– 7.4
	3 : 40 P.M.	– 11.3		6 : 05 P.M.	– 12.1		2 : 04 P.M.	9.8		4 : 53 P.M.	7.0
	9 : 46 P.M.	11.4					8 : 33 P.M.	– 8.6		11 : 25 P.M.	– 7.1
19.	4 : 05 A.M.	– 11.5	22.	12 : 09 A.M.	11.1	25.	2 : 36 A.M.	8.3	28.	5 : 31 A.M.	5.9
	10 : 10 A.M.	11.5		6 : 25 A.M.	– 11.1		8 : 53 A.M.	– 8.1		11 : 52 A.M.	– 6.2
	4 : 29 P.M.	– 11.9		12 : 30 P.M.	11.5		2 : 57 P.M.	8.7		5 : 54 P.M.	6.6
	10 : 36 P.M.	11.7		6 : 53 P.M.	– 11.6		9 : 28 P.M.	– 8.6			

Make a small circle under the number 19 to indicate the moon was full Sept. 19; and under 26 make a small semicircle convex to the left to indicate third quarter moon Sept. 26.

Questions. 1. How many flood tides each day? How many ebb?

2. As you glance over the graph, do the tide phenomena of one day appear at the same hour as those of the preceding day, or are they earlier, or later? Subtract the times of the tides Sept. 17 from the times of the corresponding tides Sept. 18, and the times of the tides Sept. 18 from the times of the corresponding tides Sept. 19; repeat the process for two more days. What is the average difference in time between the tides of one day and the corresponding tides of the next day?

3. How many hours and minutes on the average from one flood to the next flood? From ebb to ebb? From flood to ebb?

4. A day or two after what phase of the moon are the floods uncommonly high? They are called "spring tides." When are the floods uncommonly low? They are called "neap tides." N.B. Spring tides occur also after new moon, and neap tides after first quarter.

5. How does the neap ebb compare with the spring ebb?

6. How much is the neap tidal range (height of flood above ebb)? How much is the spring range? What fraction of the spring range is the neap range? N.B. The contrast between spring and neap here shown is greater than the average.

Advanced Questions. 7. On a precipitous coast would there be much, or little, horizontal movement of water in the rising or the falling tide?

8. How would the tide be of any importance in the use of shallow harbors?

9. Why do vessels sometimes start on their voyages at such an unseemly hour as 2 or 3 A.M.?

NEW JERSEY. ATLANTIC CITY SHEET

Purpose. To study the sea border of a low growing plain.

Description of the Region. The part of New Jersey adjoining the region represented on this map is a sandy plain, generally not fertile, and covered with a growth of inferior pines. The altitude is low, the relief slight, and marshes border the streams. The fertile tracts are cultivated, and considerable fishing is done along the coast, but the seaside resorts, many of which are open all the year, furnish the chief occupation of the people.

Location and Extent. 1. In what part of New Jersey is this region? In what geographic district?

2. How many miles long is the shore of the mainland, west of the great marsh, in the northwest corner of the map?

Relief and Shore Features. 3. The beaches, which make the actual sea border, lie how far from the mainland?

4. What lies between the beaches and the mainland?

As the tide comes in, the creeks are filled with sea water; as the tide goes out, the smaller creeks are completely drained and the larger ones partly emptied.

5. What part of the marsh is being artificially drained (straight blue lines) and so made serviceable?

6. From what names do you infer that the bays and connecting waterways are navigable to small boats and yachts?

7. How wide are Brigantine and Island beaches? How long is each?

8. What is their highest altitude? Is much or little of them over 10 feet above sea level?

9. How does the north end of Absecon Beach compare with the other beaches in width and altitude? Give a reason for the location of Atlantic City.

10. Do the ends of the beaches of this sheet generally "hook" toward the mainland or toward the ocean? Give a reason.

11. How many lighthouses are there on this sheet? How many life-saving stations? Explain the need of the latter.

12. Which border of the beaches is the smoother, that toward the sea or that toward the marsh? Explain why it is so.

13. What interrupts the straightness of the line in which the mainland meets the salt marsh? What sort of a shore would a perfectly smooth coastal plain have?

Advanced Questions. 14. Make a sketch map of one of the tidal creeks and its tributaries — the small streams in the salt marsh.

15. Does the mainland within ¼ mile of the salt marsh slope more, or less, than at a distance of one or two miles back? Give reason.

16. Where did the sand of the beaches come from? What agents built it into the beaches?

17. Explain the formation of the small hills on the beaches.

18. Why are there so many seaside resorts on the New Jersey coast, and no commercial towns?

MAINE. BOOTHBAY SHEET

Purpose. To study the ocean border of a high, rocky plain well dissected by rivers.

Description of the Region. The rocks of this region are mainly hard and crystalline. The glacial ice swept most of the rock waste off into the sea. The framework of the hills is the bed rock, but the topography is considerably modified in places by glacial deposits. The depths of the water are considerable, — from nearly 200 feet in Sheepscot Bay to 50 feet in Sheepscot River at the north border of the map, 25 to 30 feet in Boothbay Harbor. This is sometimes called a coast of small fiords.

Location and Extent. 1. What part of the Maine coast is here represented?

2. How many miles in a straight line is Griffith Head from Pemaquid Point? Following the shore line it is about 100 miles.

Relief and Shore Features. 3. Give the altitudes of four or five large hills.

4. The ridges and valleys extend in what direction?

5. Give the height, the width, and the length of four of the named islands of different sizes. In what direction do they extend? Are they in line with the ridges or with the valleys of the mainland? Explain how they came to be so.

6. Describe the size and altitude of the ledges at 43° 50′ N. Why do you suppose they are not of the same material as the beaches of the New Jersey coast?

7. Are there few or many salt marshes? Where are they located?

8. Give as many evidences as you can that the land was once higher and has been somewhat submerged.

9. Are the villages located near the shore, or inland? Why there?

10. Notice the one railroad in the northwest corner of the map. Why does it not run down to Boothbay and the neighboring villages?

11. What means of transportation have the people of these villages?

12. Compare the number of lighthouses and life-saving stations here with that on the New Jersey sheet, and explain the difference.

Advanced Questions. 13. Draw a cross section to show the depth of water from the south end of Damiscove Island west to the mainland, using the following data and the standard vertical scale.

CM. FROM MAINLAND.	0	2	4	7	8	10	12	14	15	16
FEET DEEP.	0	60	84	192	102	136	198	150	90	0

14. Account for the shallow place 8 centimeters from the west end of the section.

15. Draw an outline map of Linekin Neck and shade the part that would be submerged if the land should sink 100 feet.

OREGON. PORT ORFORD SHEET

Purpose. To study a narrow coastal plain and a mountainous coast.

Description of the Region. This sheet represents a part of the coast mountains in southern Oregon, and part of a narrow coastal plain which extends from the village of Port Orford many miles north of the limits of this sheet. Although most of the rock of this region is sedimentary, volcanic intrusions and lava flows are numerous. Tower Rock, Castle Rock, Island Rock, and some other islands are probably old volcanic necks. This whole region was in late geologic times base-leveled and submerged, and has recently been elevated. Nearly everywhere the bed rock is covered by only a thin layer of rock waste, but on the coastal plain the sand and gravel varies in thickness from 20 feet at the base of the mountains to 85 feet at the sea border.

Topography and Coast Features. 1. What is the width of the plain at Cape Blanco? At the northern border of the map? What is its altitude at Denmark?

2. Note the fine brown dotted areas that represent beach sand. Is this beach sand abundant on the rocky points? On the low shores?

3. Why does not Floras Creek flow directly west into the ocean as it once did?

4. How was Garrison Lagoon, near Port Orford village, formed? Name three other bodies of water on this sheet that were similarly formed.

5. Does the sheet show that the streams of this region have steep, or gentle, grades? Therefore, do they carry much or little sediment? What evidently becomes of the sediment brought to the sea by Elk and Sixes rivers? Therefore, where are the waves building up the shore line?

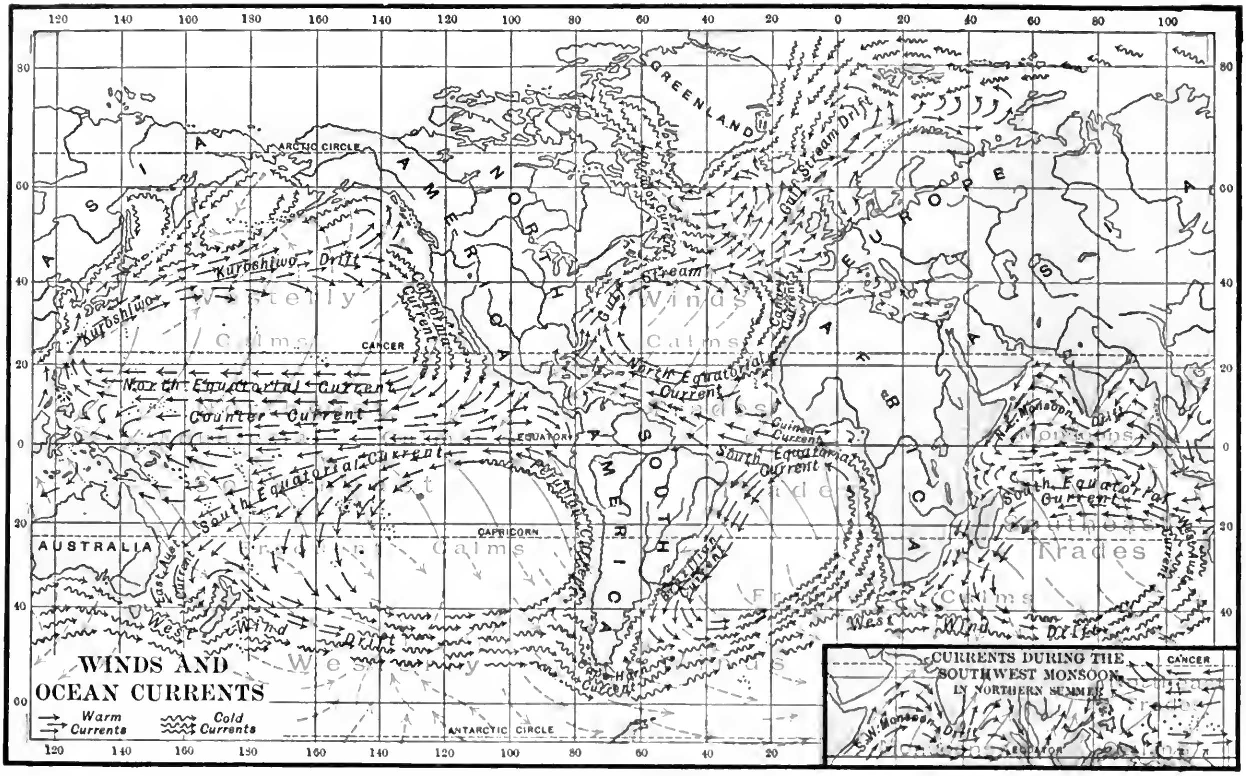
6. How does the coast line north of Point Orford compare with that to the south? Give the reasons for the differences.

7. Are most of the rocky islets located off rocky promontories, or off low beaches? Are the waves cutting, or building, at the headlands?

8. Do you find many good harbors on this rising coast? If the land should sink 100 feet, where would there be good harbors?

WINDS AND CURRENTS.

Purpose. To study the relation of the ocean surface circulation to the planetary winds.



1. Name the currents in the trade wind belts in the middle of the oceans, give the general direction in which they move, and the reason for this movement.

2. When the water driven by the trade winds reaches the western side of the oceans, what directions does it take? Give the names applied to the currents formed of these waters.

3. Name the currents and drifts which have an easterly direction in latitudes 40° to 60°, and give a reason for their direction.

4. Explain what becomes of the water of each of these drifts when it reaches the eastern side of the oceans, and give the names of the currents formed of it.

5. What is the direction of the drift in the Indian Ocean north of the equator in winter (large map)? In summer (small corner map)? Explain the difference.

6. Give the latitude and the longitude of the center of each of the five large ocean areas that have no current. Explain why there are no currents here.

7. Name the currents or drifts that exert a cooling influence on the shores they wash, and name the countries thus affected by each.

8. Name the currents or drifts that exert a warming influence, and the countries thus affected by each.

OCEAN ROUTES

Purpose. To learn how ocean routes are influenced by prevailing winds, by storms and currents.

Material. Pilot charts of the North Pacific and North Atlantic oceans, a globe, a string.

A. The North Pacific Ocean. To find the shortest course vessels could take from San Francisco to Yokohama, Japan, stretch a string on a globe between these two places.

1. Is it an east-west line?

On the North Pacific Pilot Chart this is called the Great Circle Route between San Francisco and Yokohama.

2. How many miles long is it?

3. Reckoning $54\frac{1}{2}$ miles to a degree, how many miles are there from San Francisco to Yokohama in an east-west line? How much different from the great circle route?

4. Give a reason why the sailing route from Yokohama to San Francisco is so different from the sailing route from San Francisco to China and Japan.

5. State and explain the difference between the sailing route from Juan de Fuca to San Diego and that from San Diego to Juan de Fuca.

6. Describe the general path of typhoons. In what months are they most frequent? (See Table of Storm Tracks.)

B. The North Atlantic Ocean. 7. Explain the difference between the sailing route from the English Channel to the equator and that from the equator to the English Channel.

8. Describe the route from New York to the equator, and explain why the return route is different.

9. Why do sailors going from London to New York sometimes go as far south as latitude 25° N.? On the return voyage would they take the same course?

10. Dense fogs are common on the Grand Banks southeast of Newfoundland from late winter till early summer. Icebergs and floes (small red triangles and circles) are frequent there in summer. On account of these dangers how do the spring and summer steamer routes differ from the fall and winter routes?

11. To avoid collisions in fog or storm the east-bound steamer routes from New York to Europe do not coincide with the west-bound routes. Which lies further north?

12. What vessel routes lie in the Gulf Stream going northeast but avoid the Stream going in the opposite direction?

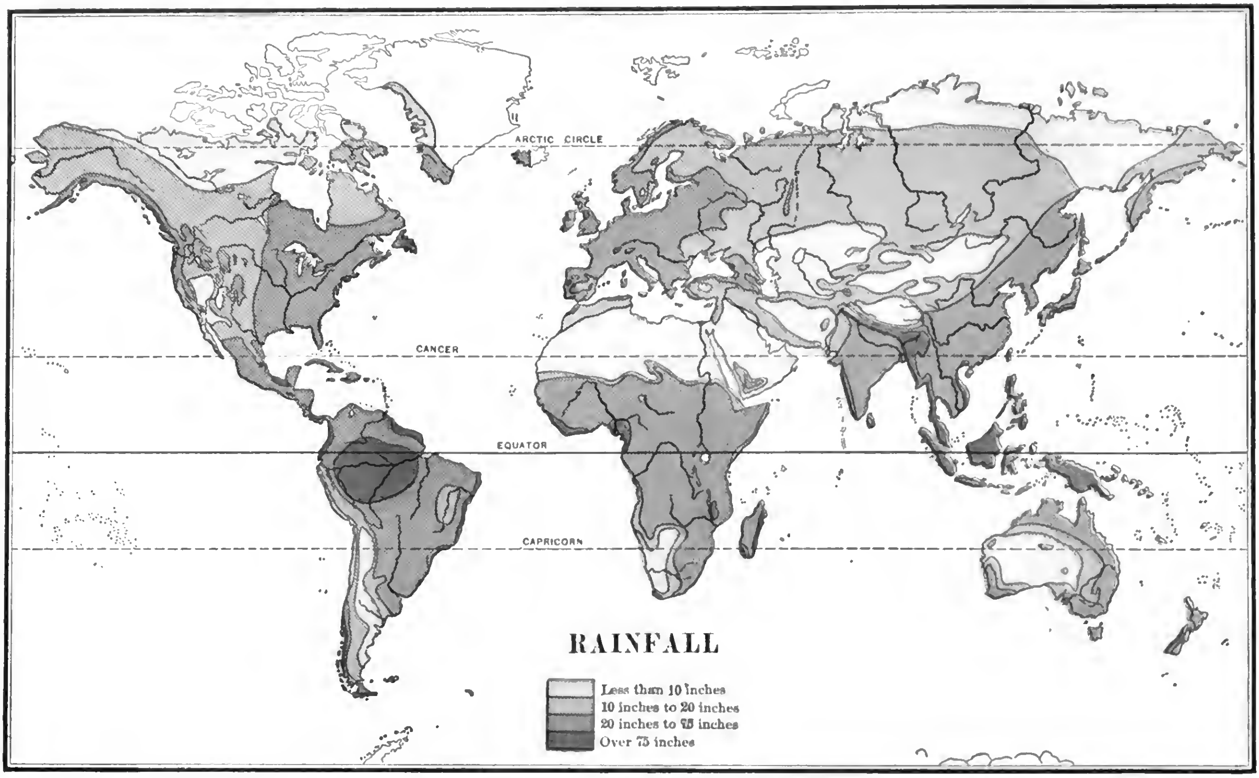
13. Heavy red lines mark the storm paths. Routes in what latitudes are most subject to storms?

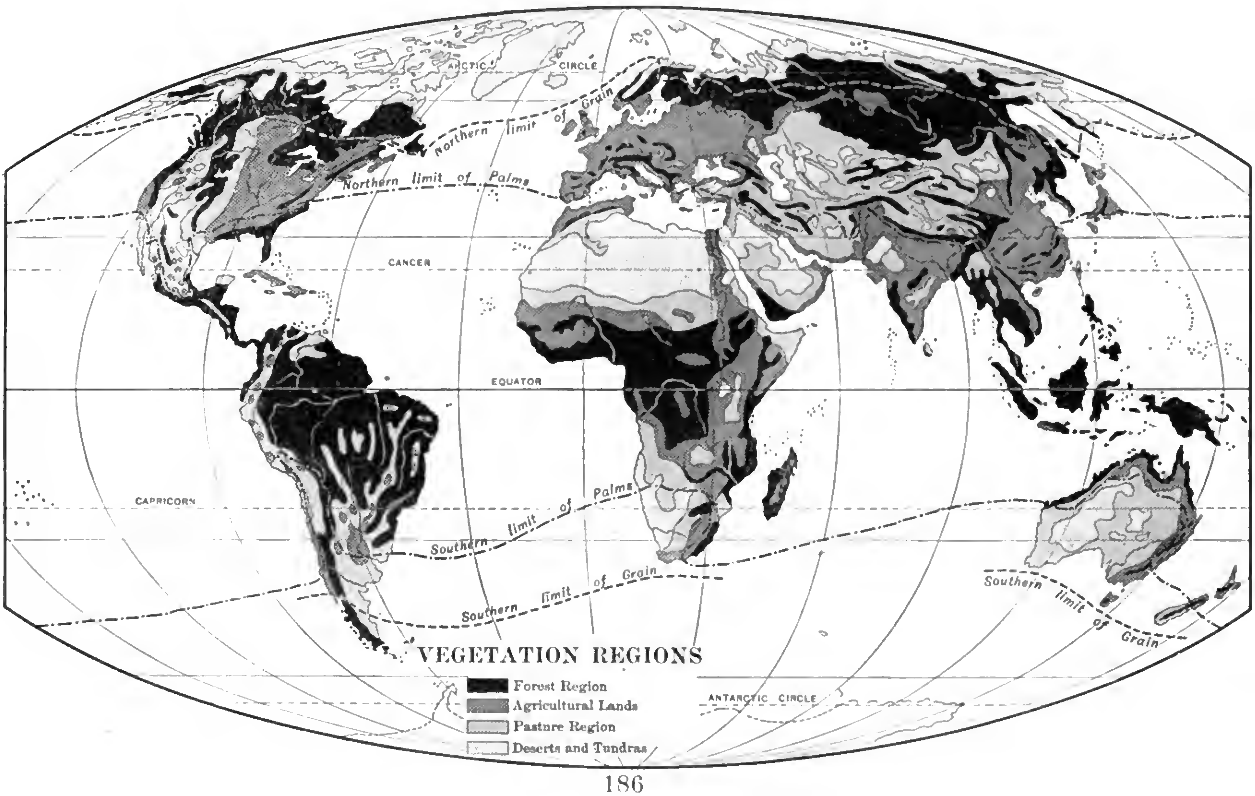
14. If you find any hurricane paths mapped, describe the path and give the months in which the storms occur.

Advanced Questions. 15. Water currents and drifts are marked by small black arrows. Locate the places in either ocean where the surface water movement corresponds with the prevailing wind direction.

16. What kinds of vessels seem to prefer great circle routes? What kinds adapt their routes more to the prevailing winds?

17. Of the hundreds of ships plying between Europe and America, why does a voyager meet so few? In what part of his route does he see the largest number?


ARCTIC CIRCLE
CANCER
EQUATOR
CAPRICORN
RAINFALL
Less than 10 inches
10 inches to 20 inches
20 inches to 75 inches
Over 75 inches


ARCTIC CIRCLE
Northern limit of Grain
Northern limit of Palms
CANCER
EQUATOR
CAPRICORN
Southern limit of Palms
Southern limit of Grain
Southern limit of Grain
VEGETATION REGIONS
Forest Region
Agricultural Lands
Pasture Region
Deserts and Tundras
ANTARCTIC CIRCLE

RAINFALL AND VEGETATION

Purpose. To study the distribution of rain over the earth, and the vegetation areas and belts depending on rainfall and temperature.

A. Rainfall. (Turn to your study of the Terrestrial Wind Belts, p. 151, and review the latitudes, and direction of winds, of each belt.)

1. What belt around the earth has the heaviest rainfall? In what wind belts is it?

Are there any dry regions in it?

2. Between what latitude boundaries are the large desert areas that are crossed by the tropic of Cancer? By the tropic of Capricorn?

On which side of the land masses do these desert areas extend down to the ocean? Explain why this is so.

3. At what places in these dry belts is the rainfall heavy? On which side of the continents are these places? Give a reason for these heavy rainfalls.

4. In what wind belt are the dry areas of Central Asia and the United States? Do these deserts extend to the ocean on either side of the continent? Give a reason. Give the location of a corresponding dry region in the southern hemisphere.

B. Vegetation. 5. Give the general location of each of the two belts which include most of the great forest regions of the earth.

The forests of the torrid belt are very different from those of the cool belt. The latter are mostly of spruces, firs, and pines; while the former include a large variety of broad-leaved trees.

6. Carefully compare the two maps. Are the forest regions generally areas of heavy, or of light rainfall? Name four comparatively small regions that illustrate your answer.

7. Are the pasture regions areas of light or of heavy rainfall? Name several regions which illustrate your answer.

8. How many inches of rainfall do most of the large agricultural regions receive? Why, then, in Egypt, which receives a desert rainfall, is a strip marked agricultural?

9. Does the northern or the southern hemisphere have the large tundra regions? Why?

Advanced Questions. 10. In which hemisphere, the northern or the southern, do the areas of palms and of grain extend nearer the pole? Give reason.

11. Taking 20 inches of rainfall as the dividing line, do the dry areas, or the moist, occupy the larger portion of the land surface? Name a continent in which the opposite condition prevails.

12. Why is the southern part of South America rainy on the west side, while southwestern Africa is desert?

13. Are the long, narrow forest regions of Europe and Asia on mountains or in valleys? Why?

Compare these two pictures, one representing a cold-climate forest, the other representing an equatorial forest.

1. In which would a man find more obstruction by bushes and vines?

2. In which are the trunks set more closely together?

3. How has this crowding and consequent loss of sunlight affected the lower branches of the spruce?

4. Which forest would produce the straighter timber?

5. In what two ways are the spruce branches adapted to shed the snow?

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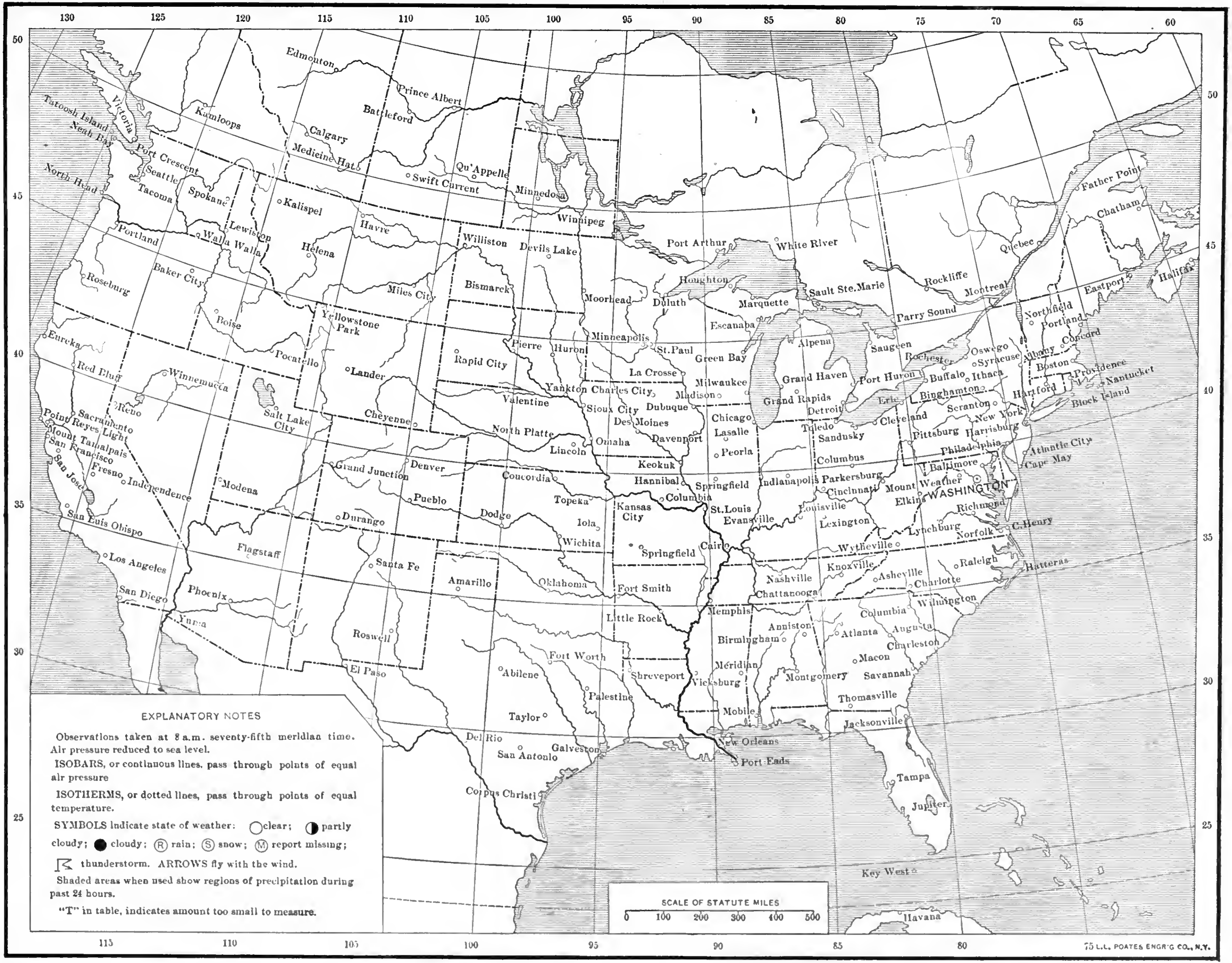
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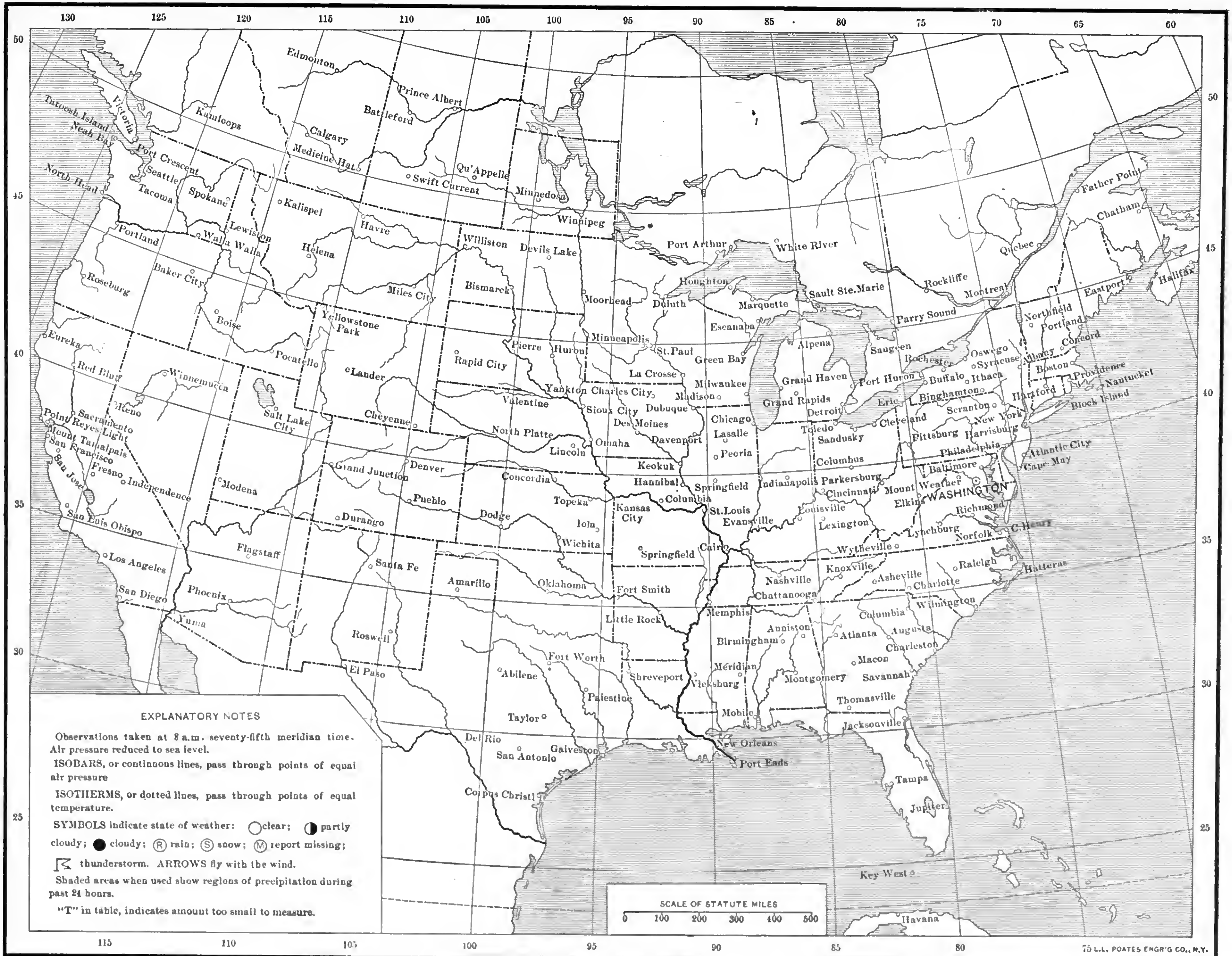
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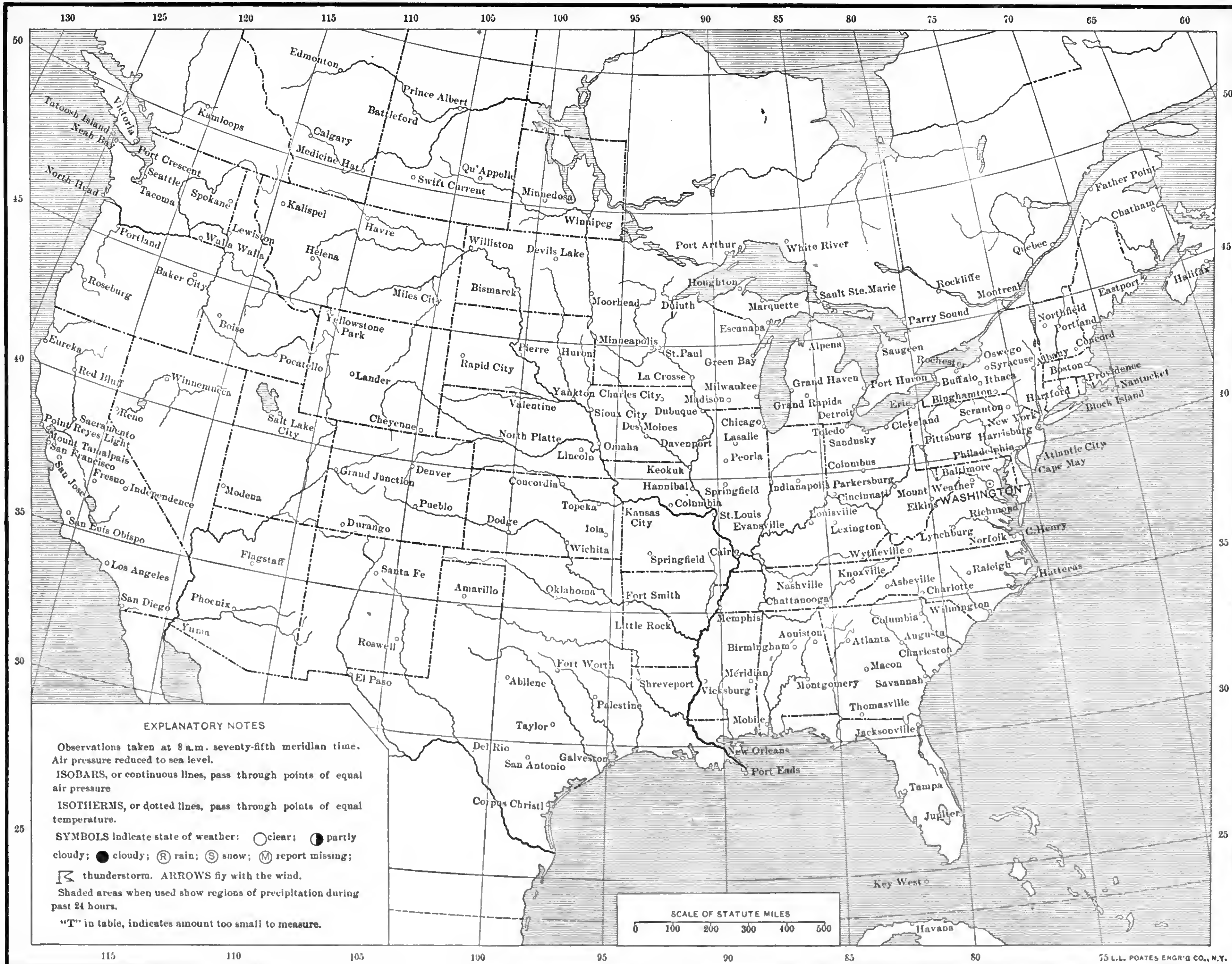
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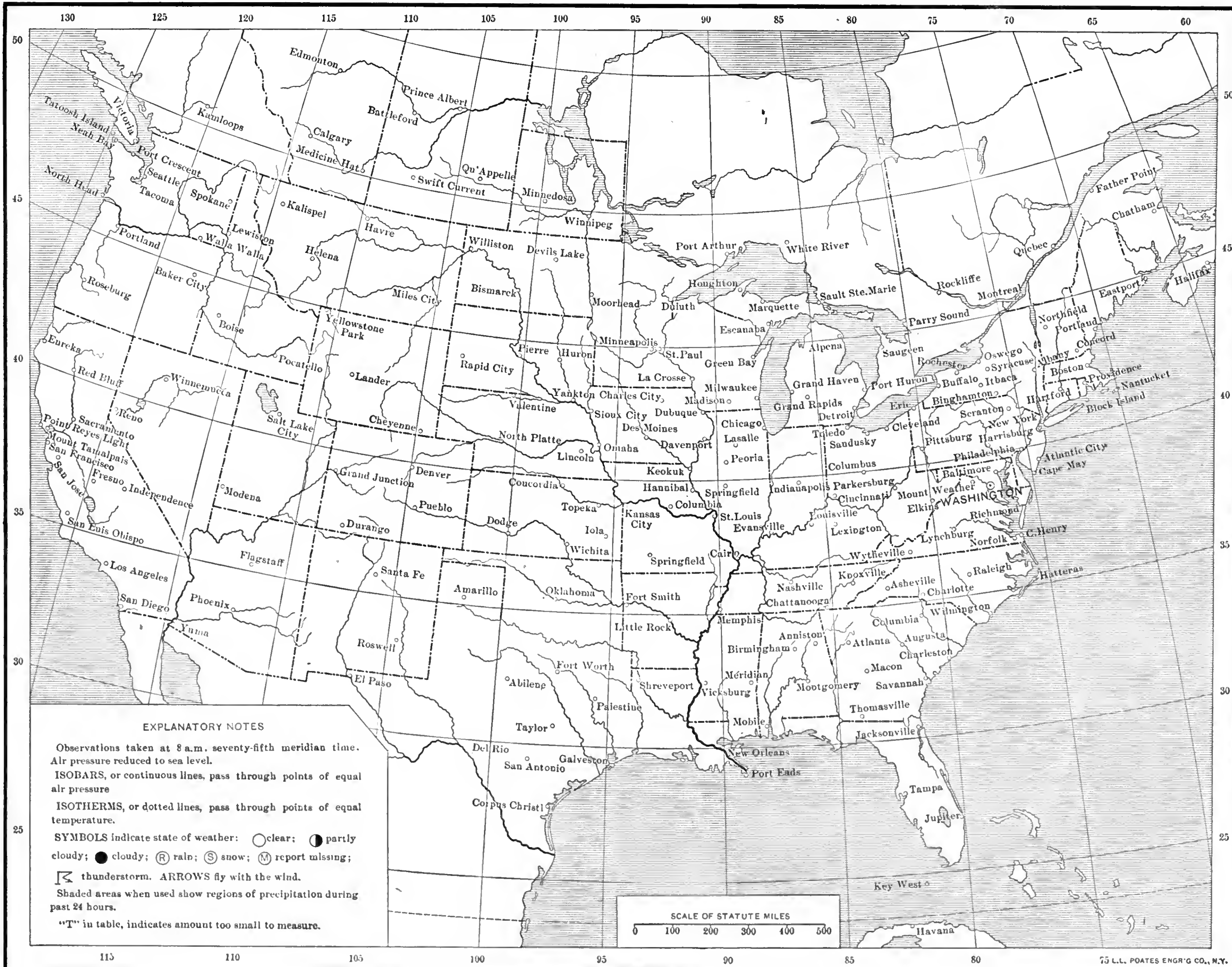
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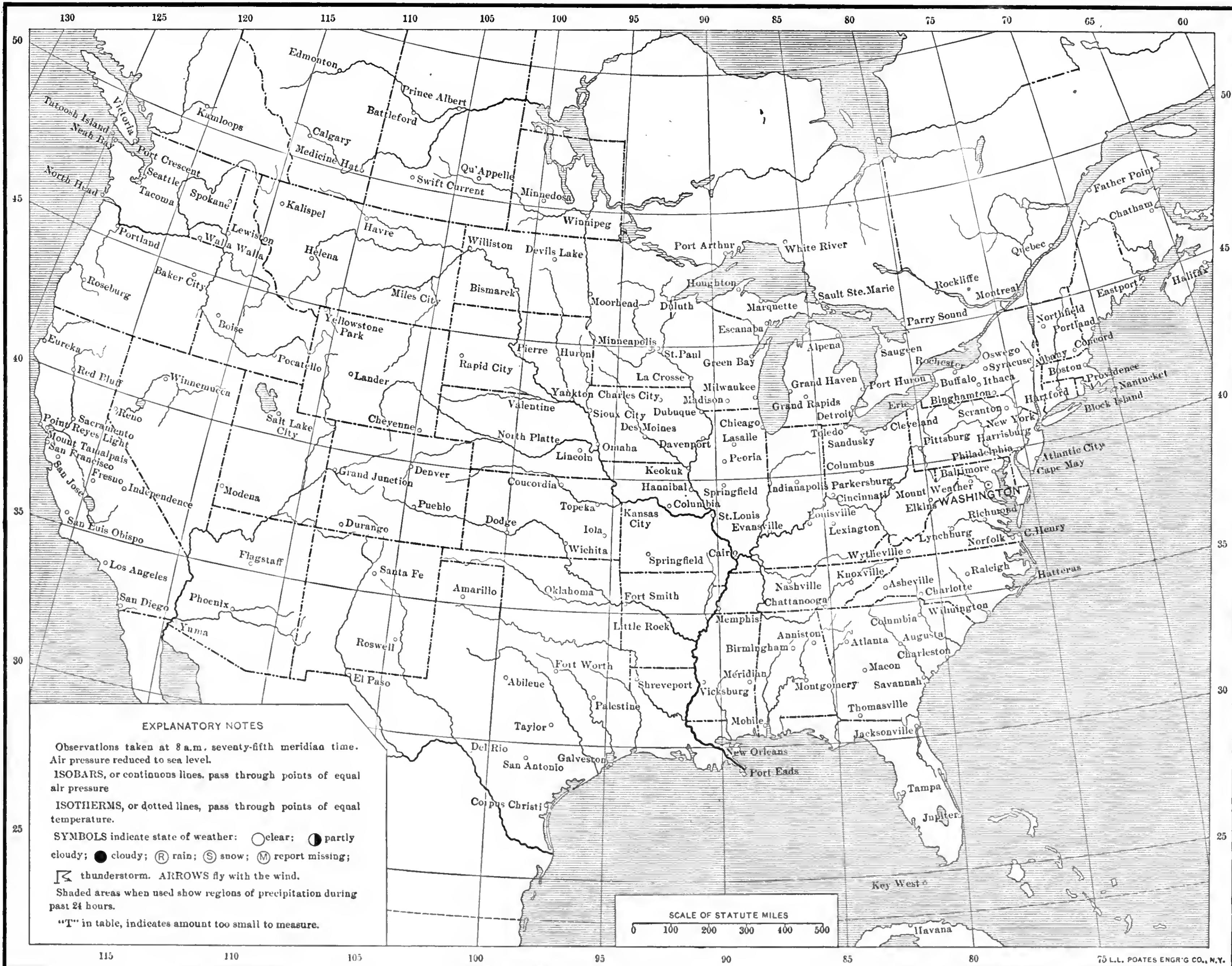
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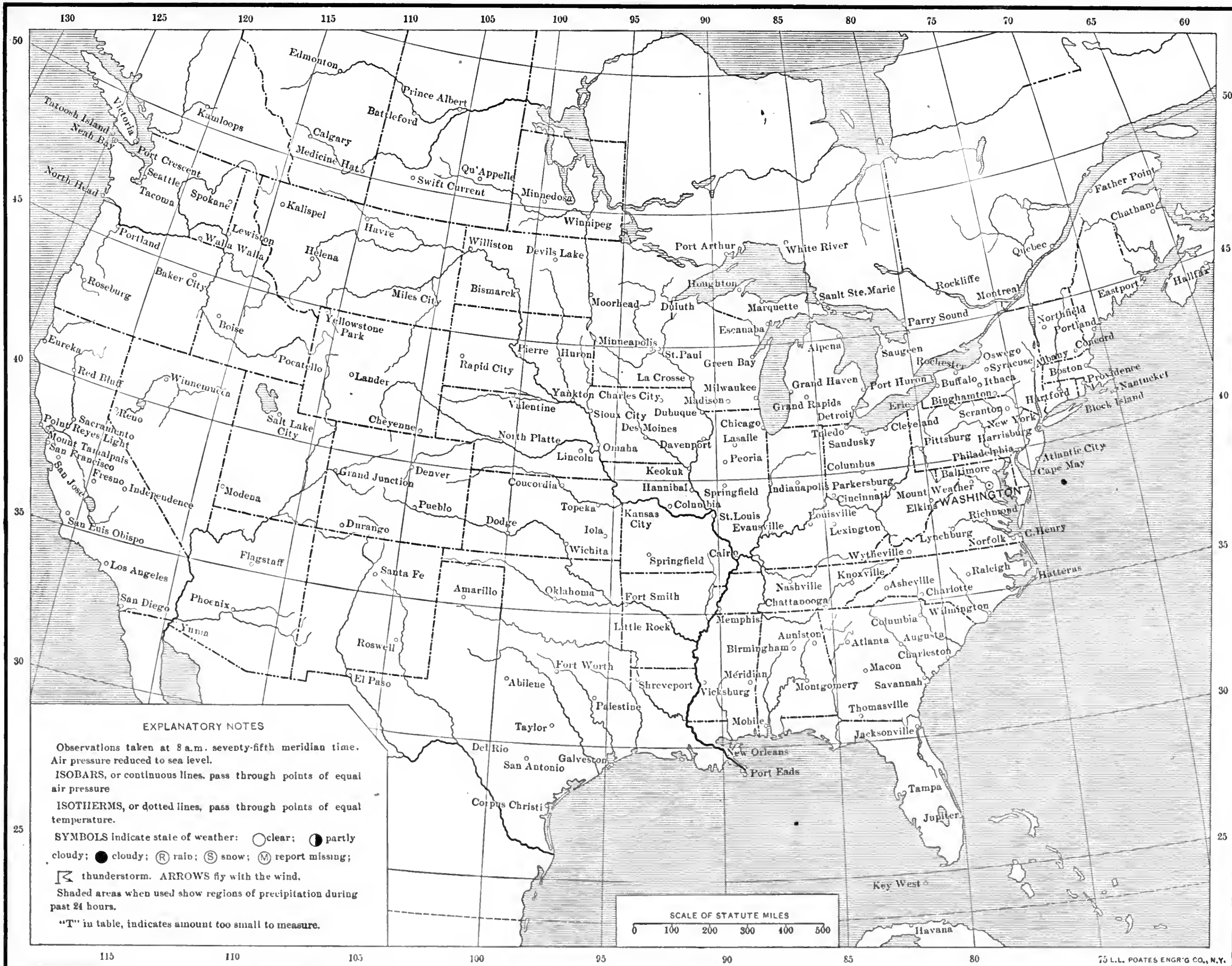
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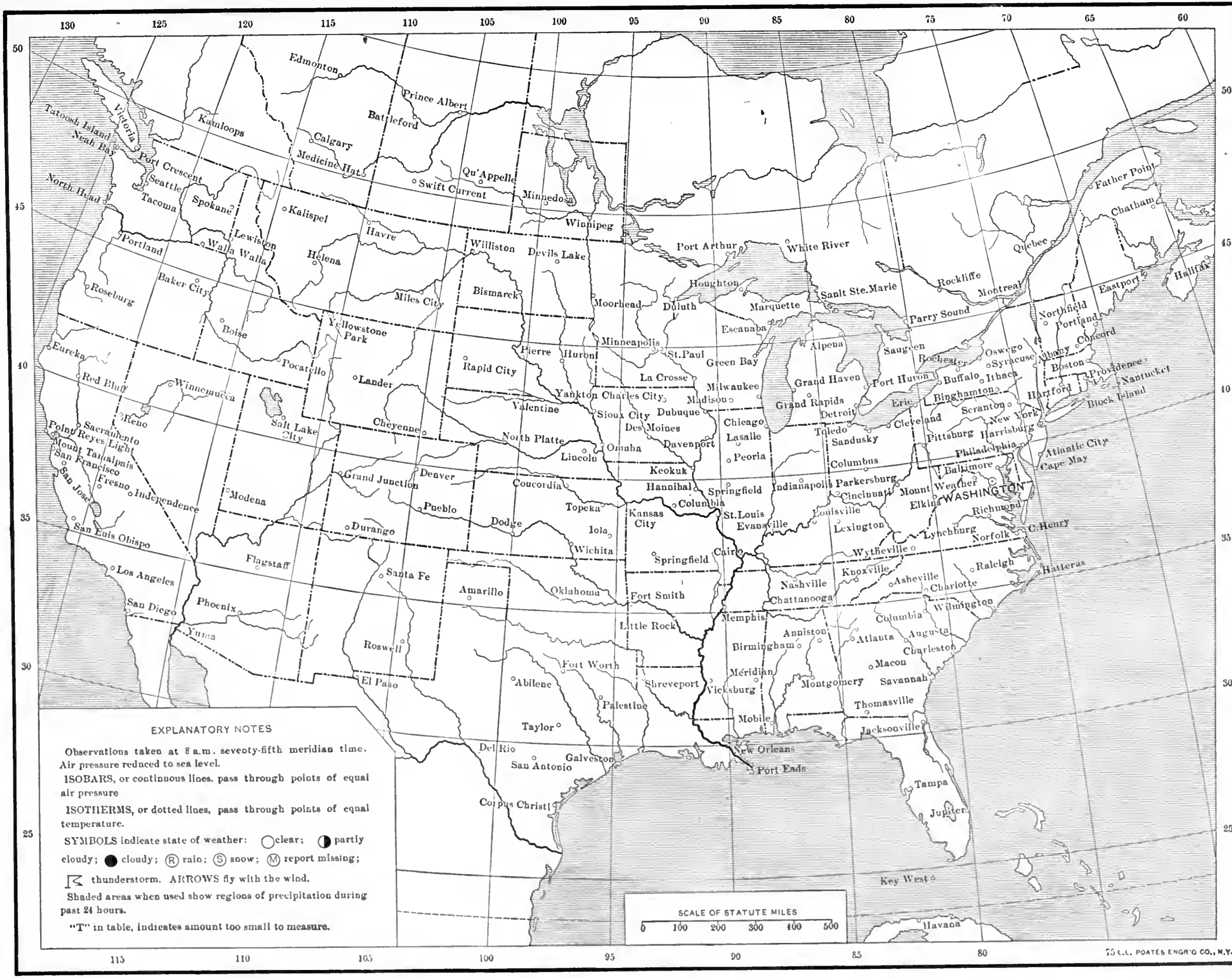
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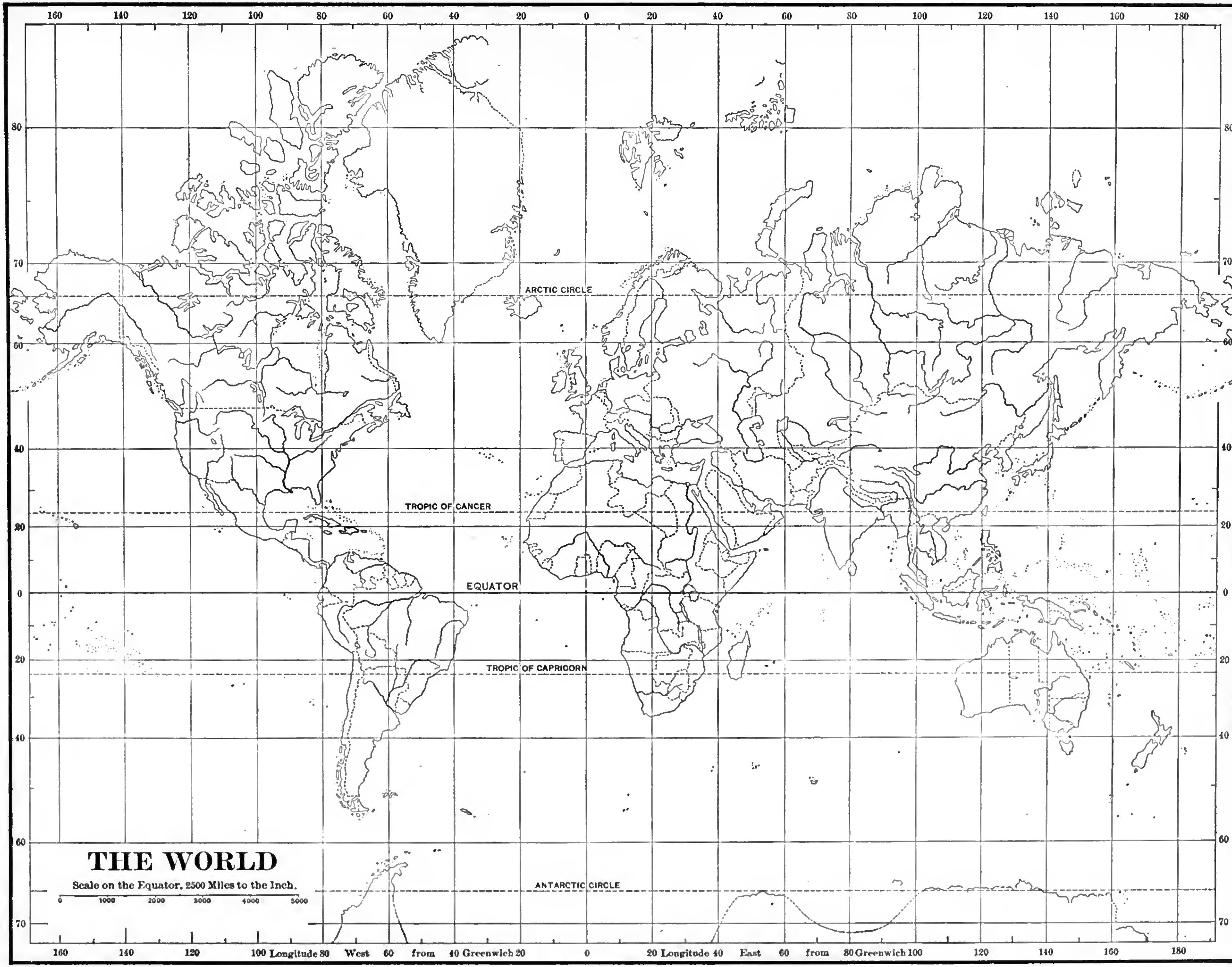
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Scale on the Equator, 2500 Miles to the Inch.
0 1000 2000 3000 4000 5000
ARCTIC CIRCLE
TROPIC OF CANCER
EQUATOR
TROPIC OF CAPRICORN
ANTARCTIC CIRCLE
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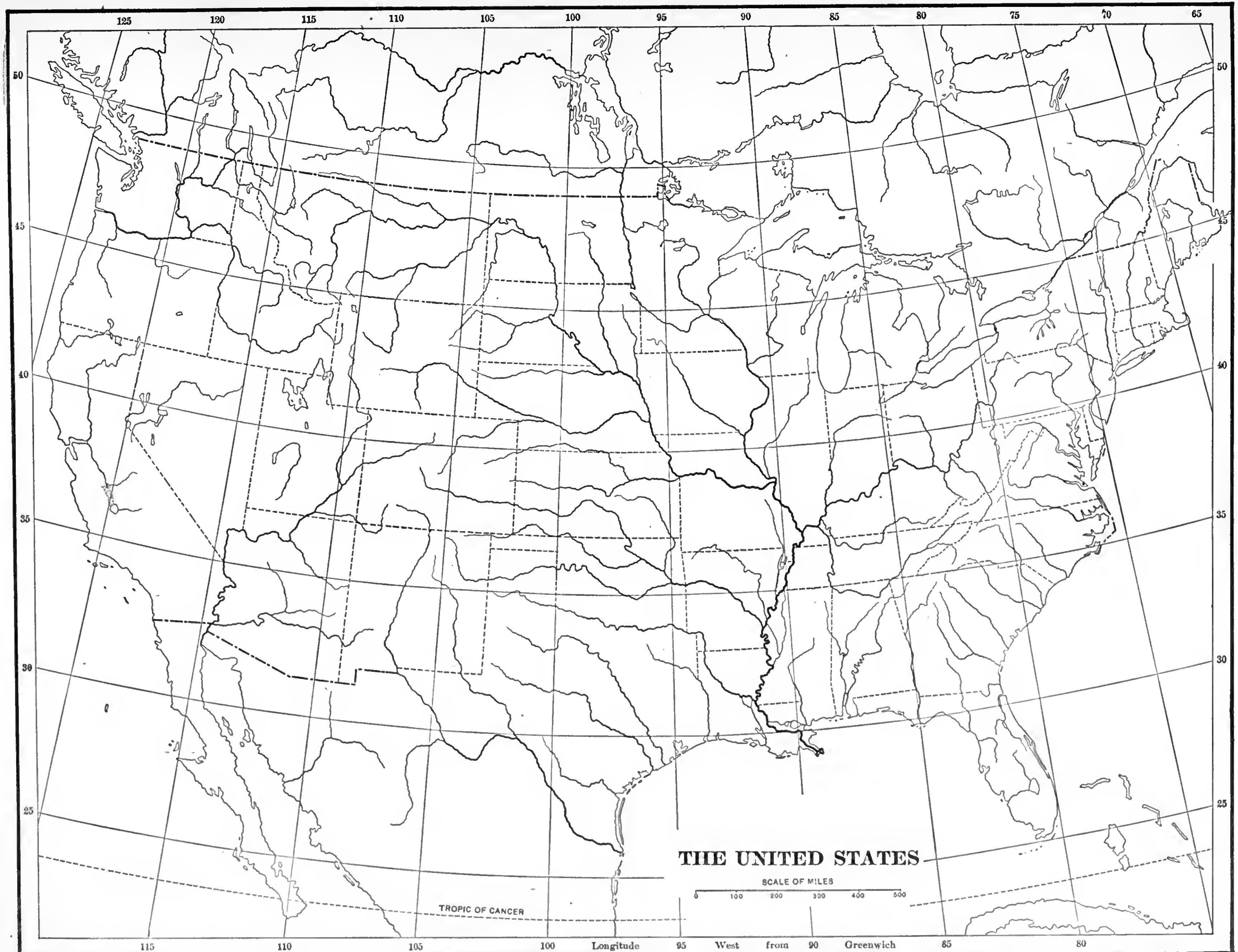
THE UNITED STATES
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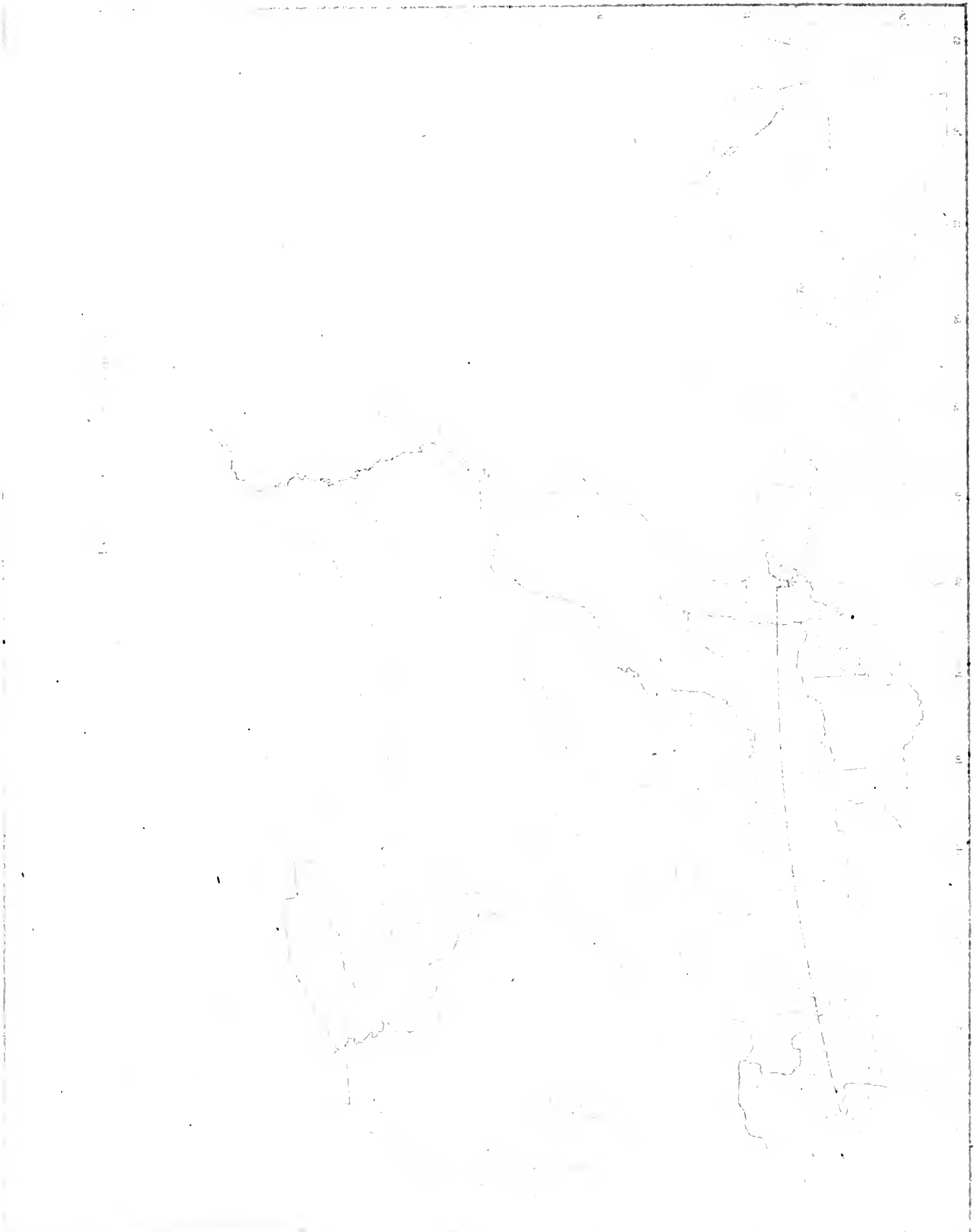

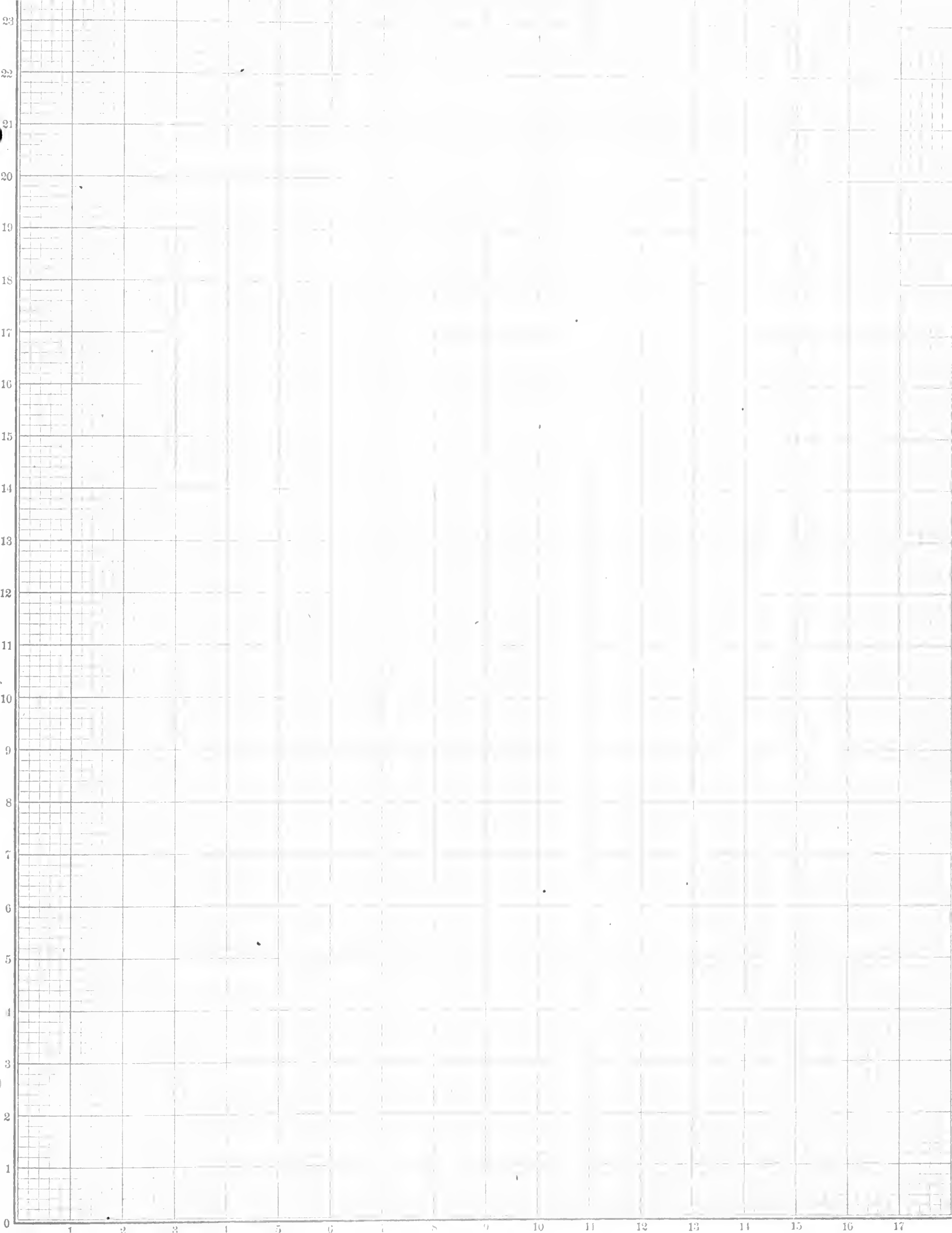
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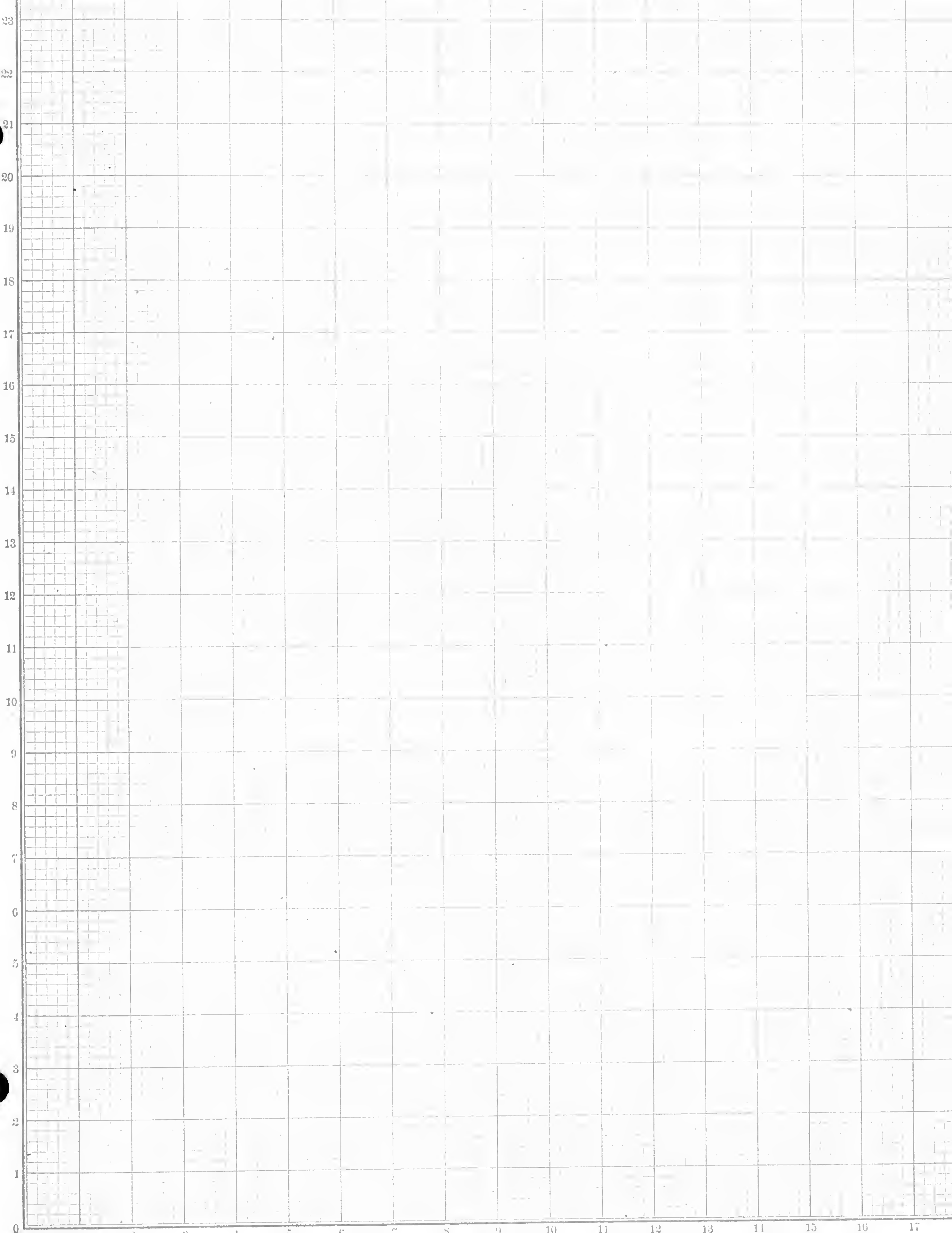
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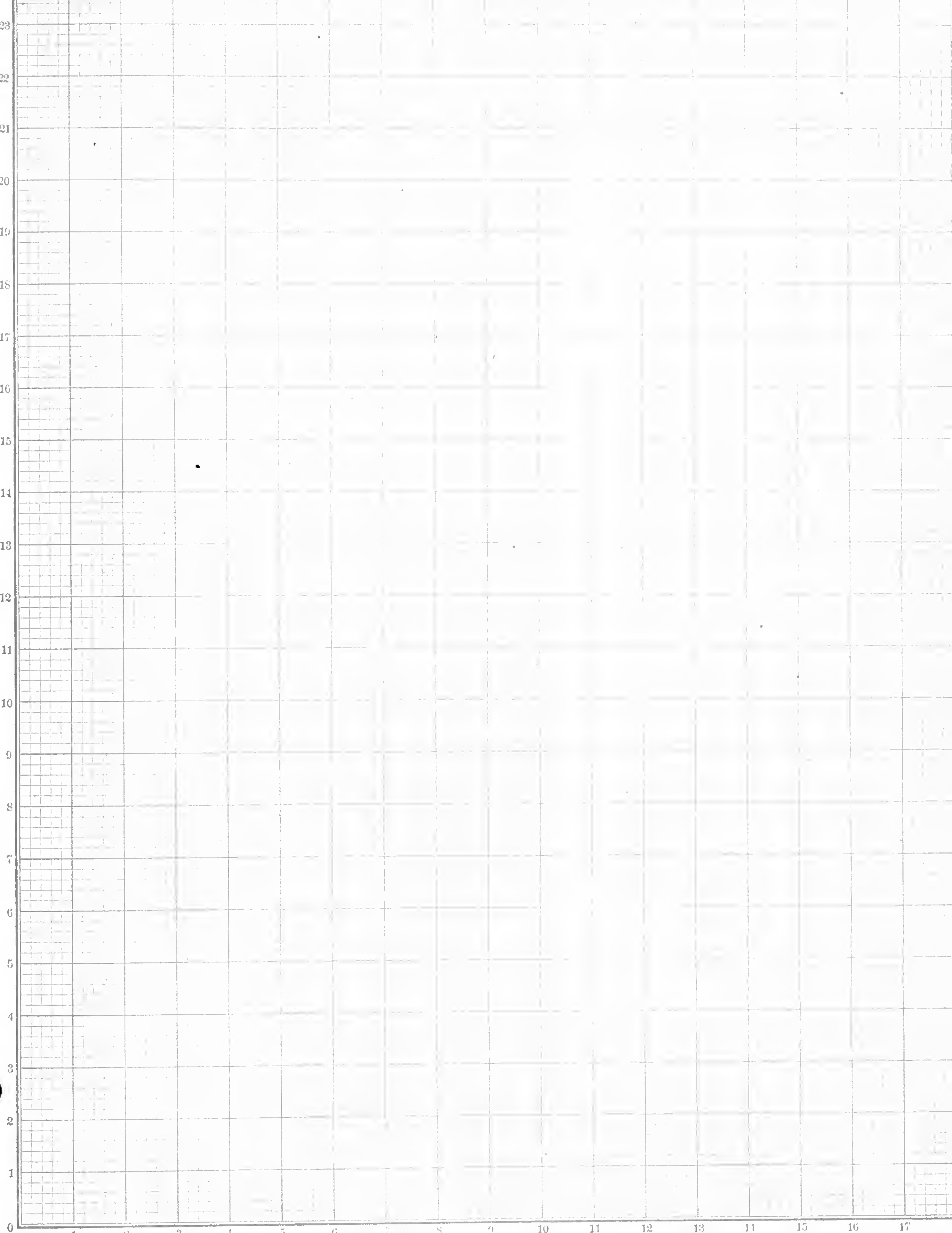
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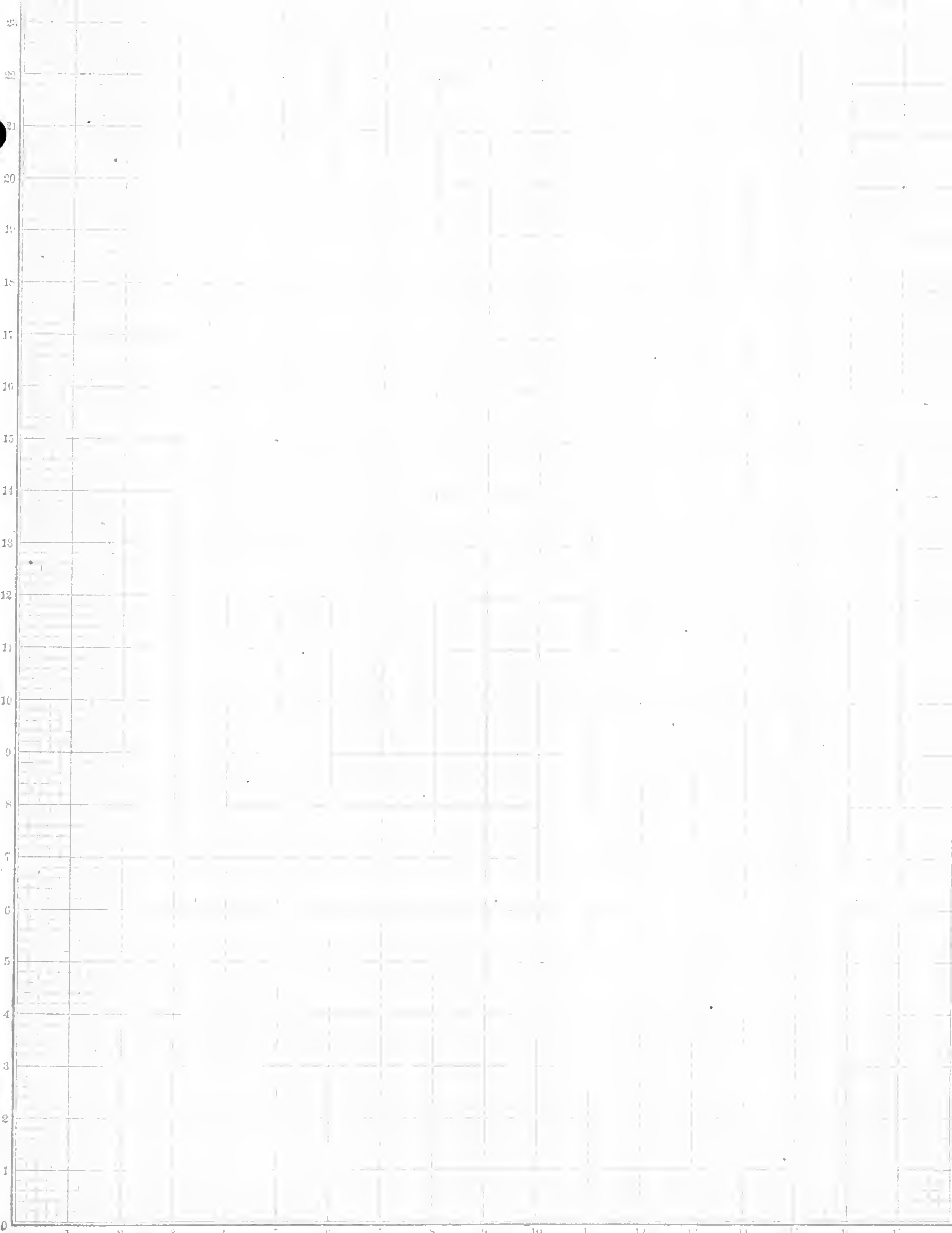

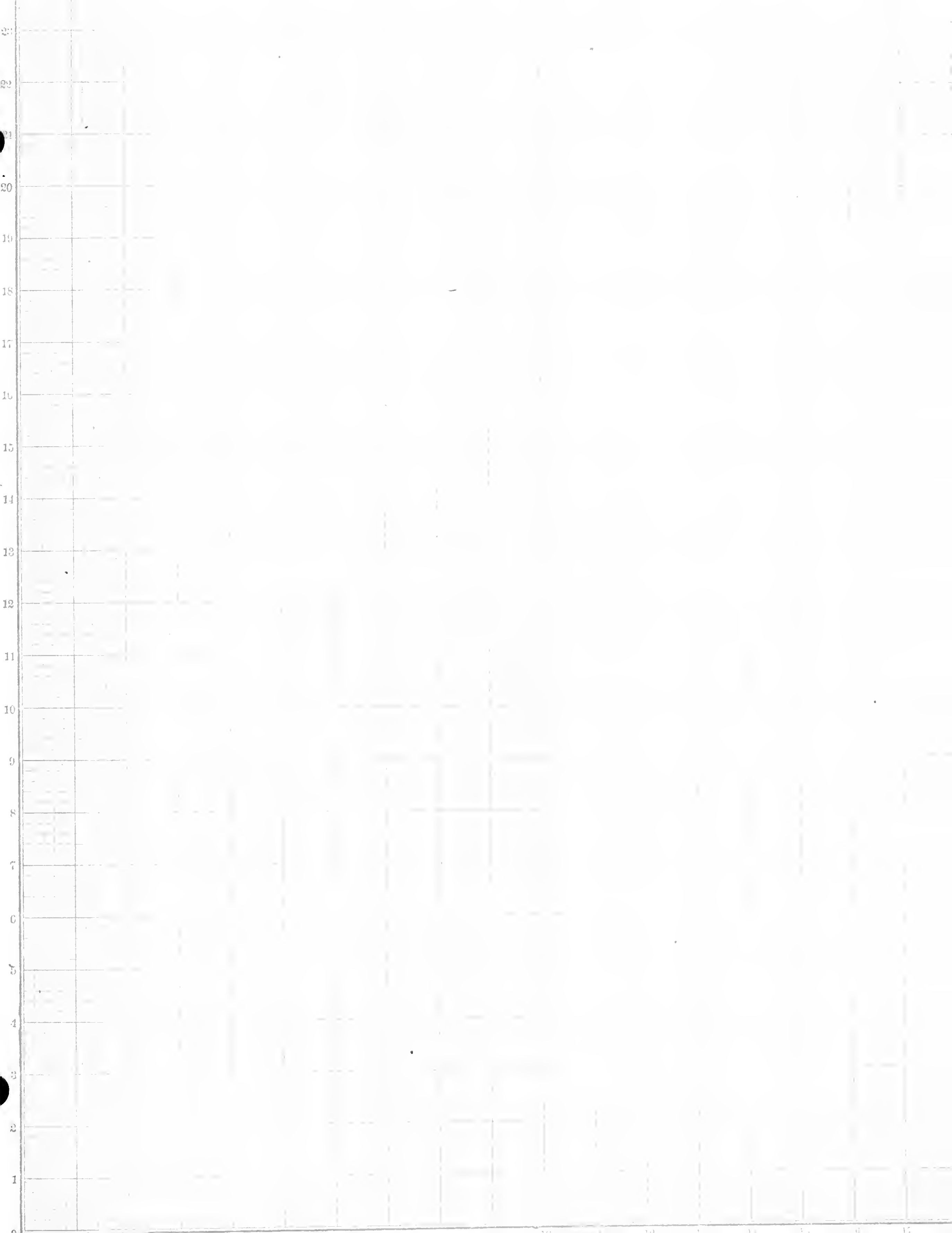

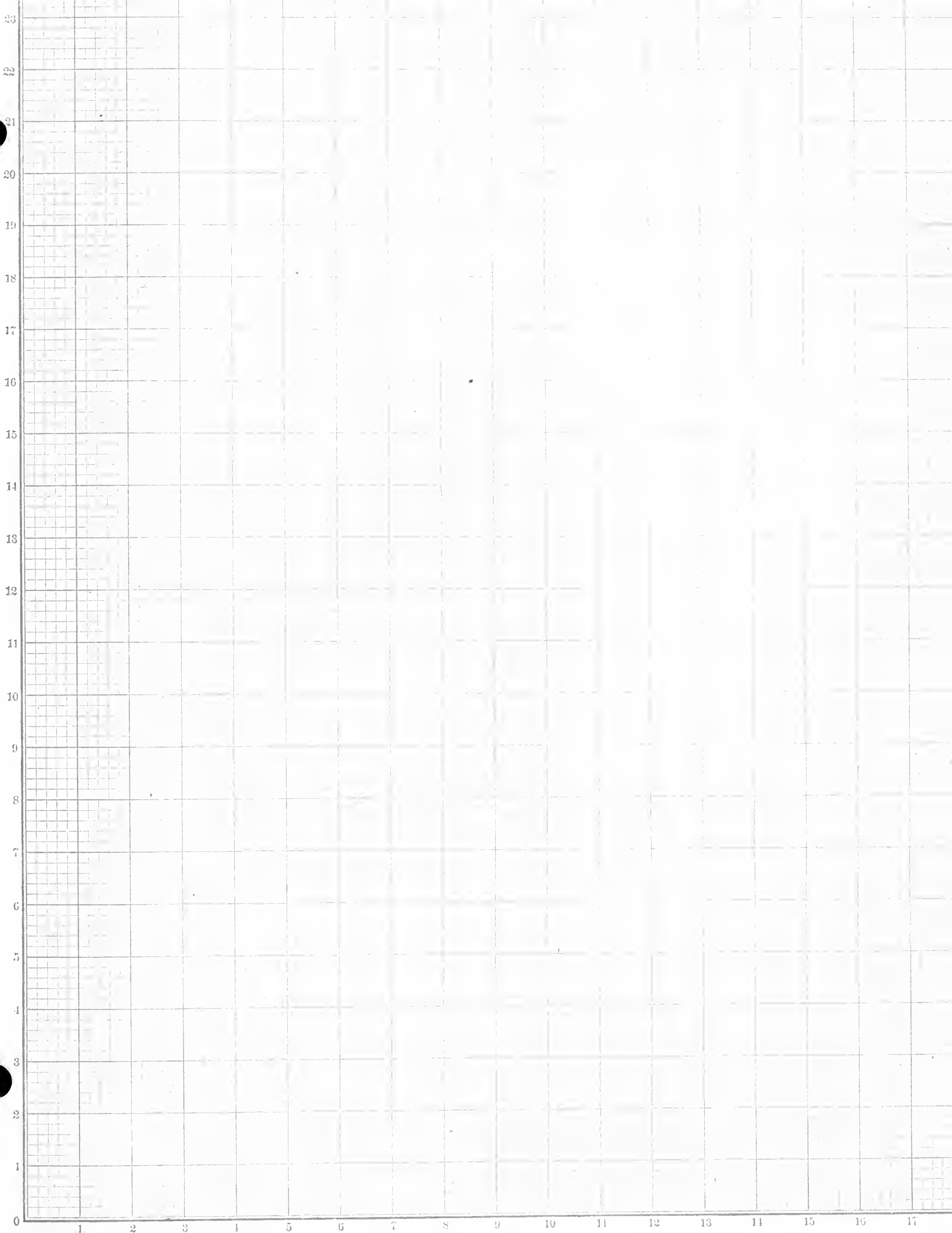
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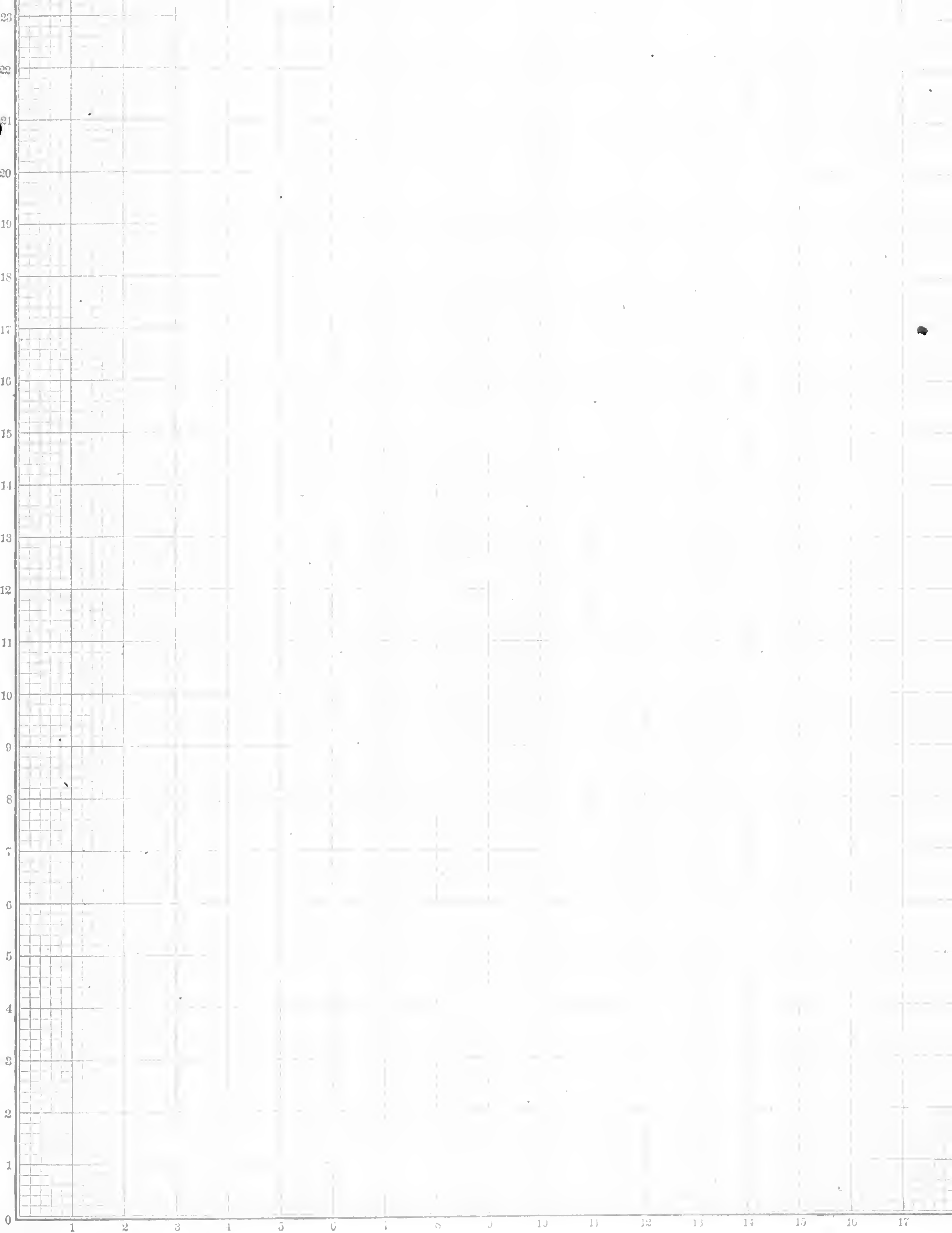
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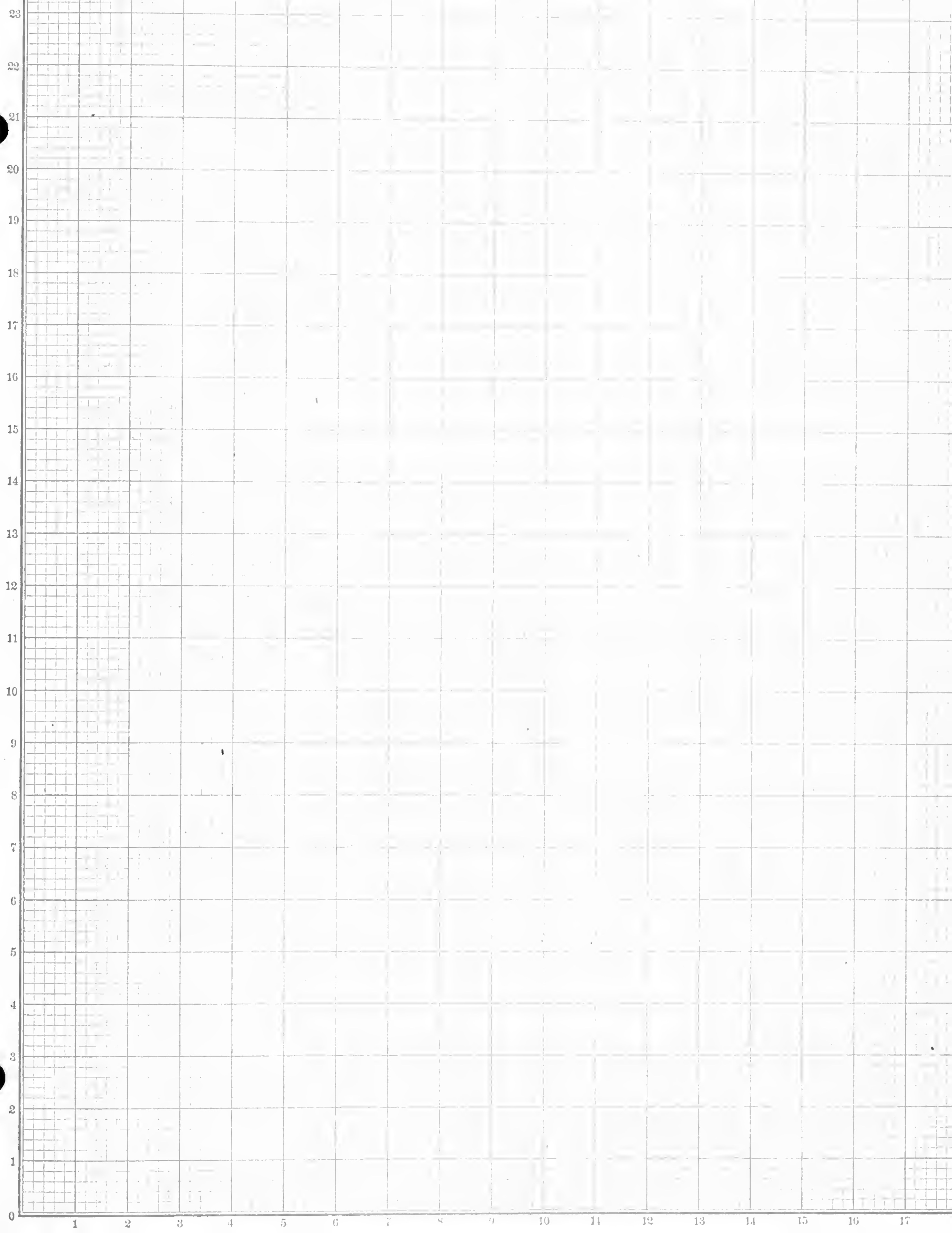
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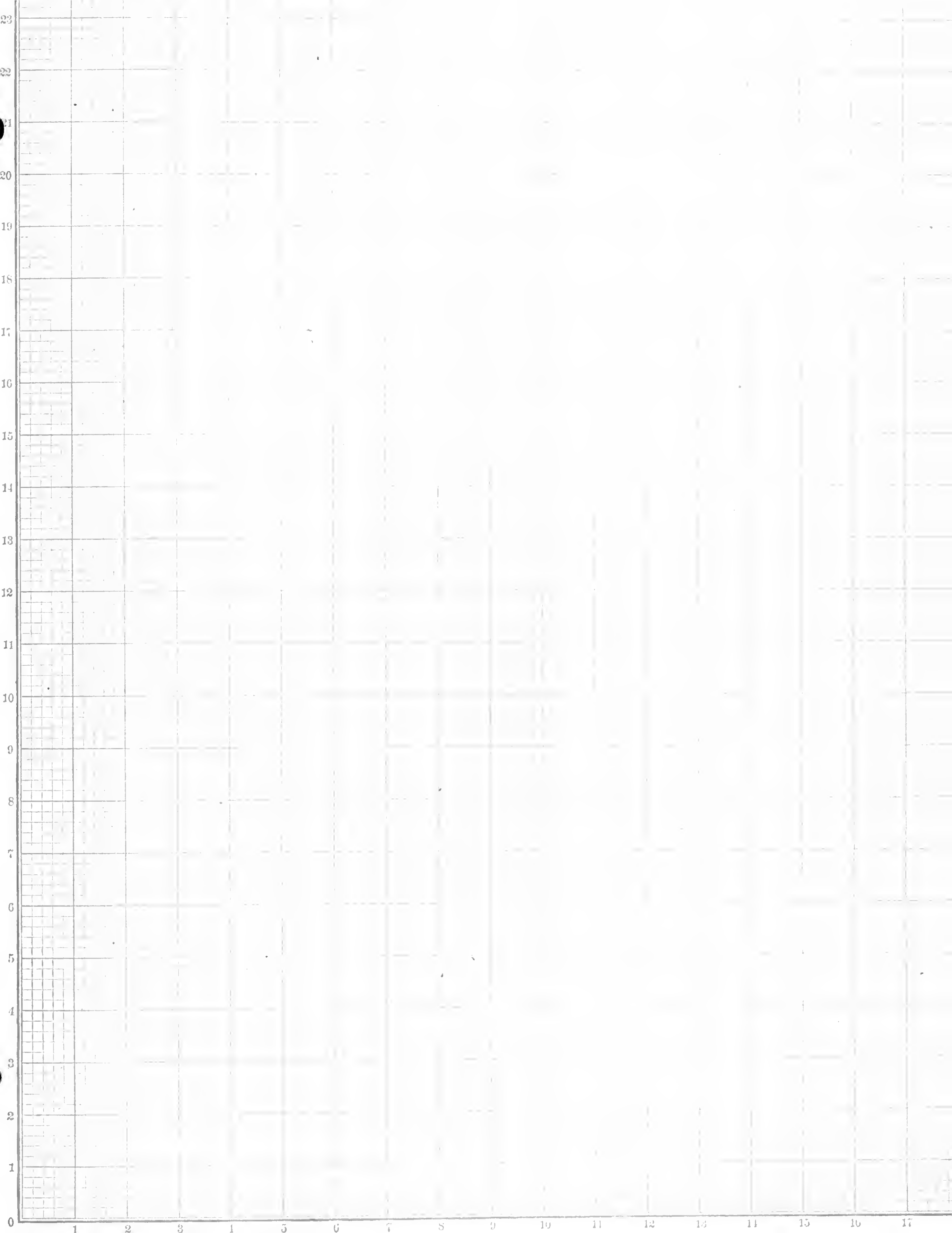
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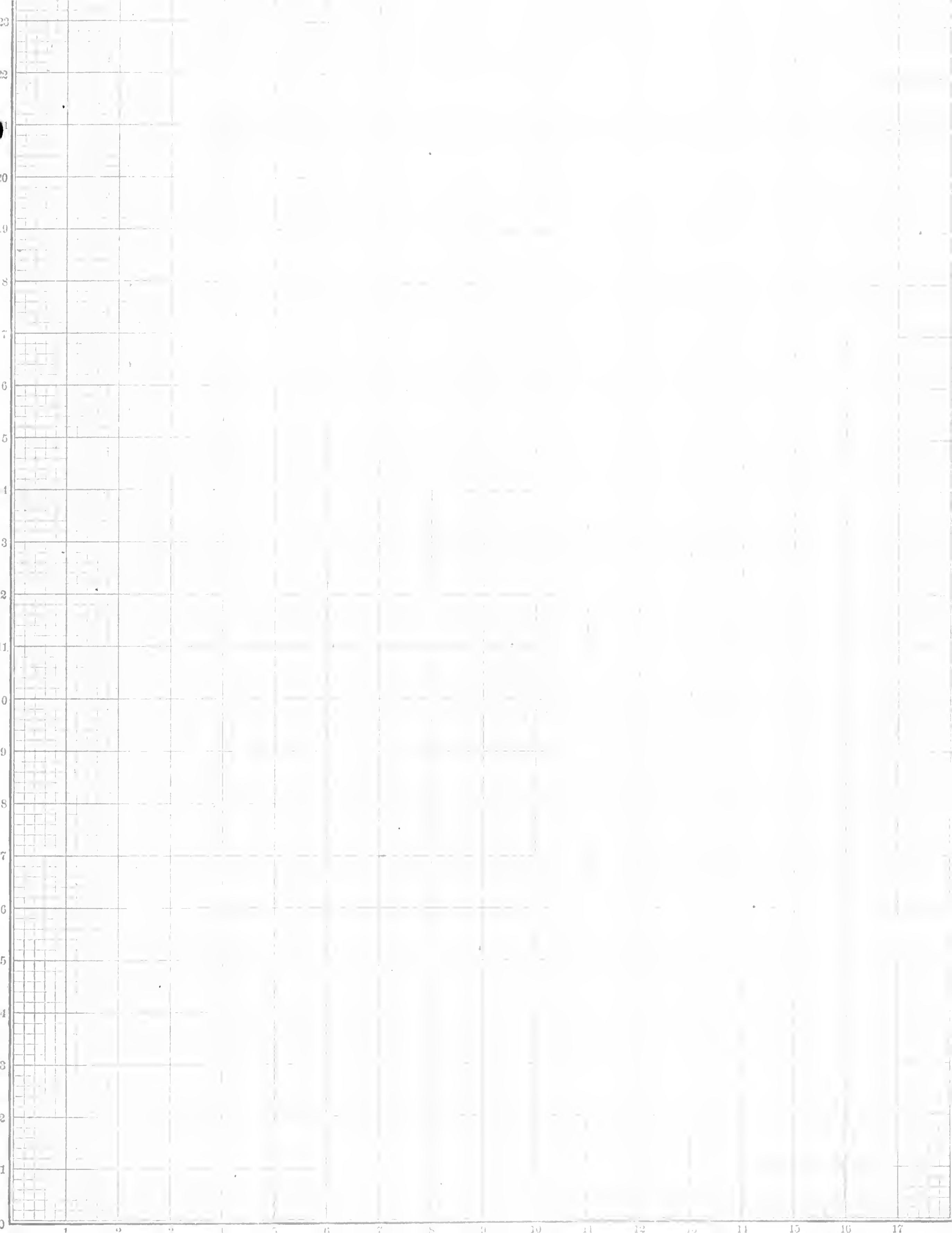

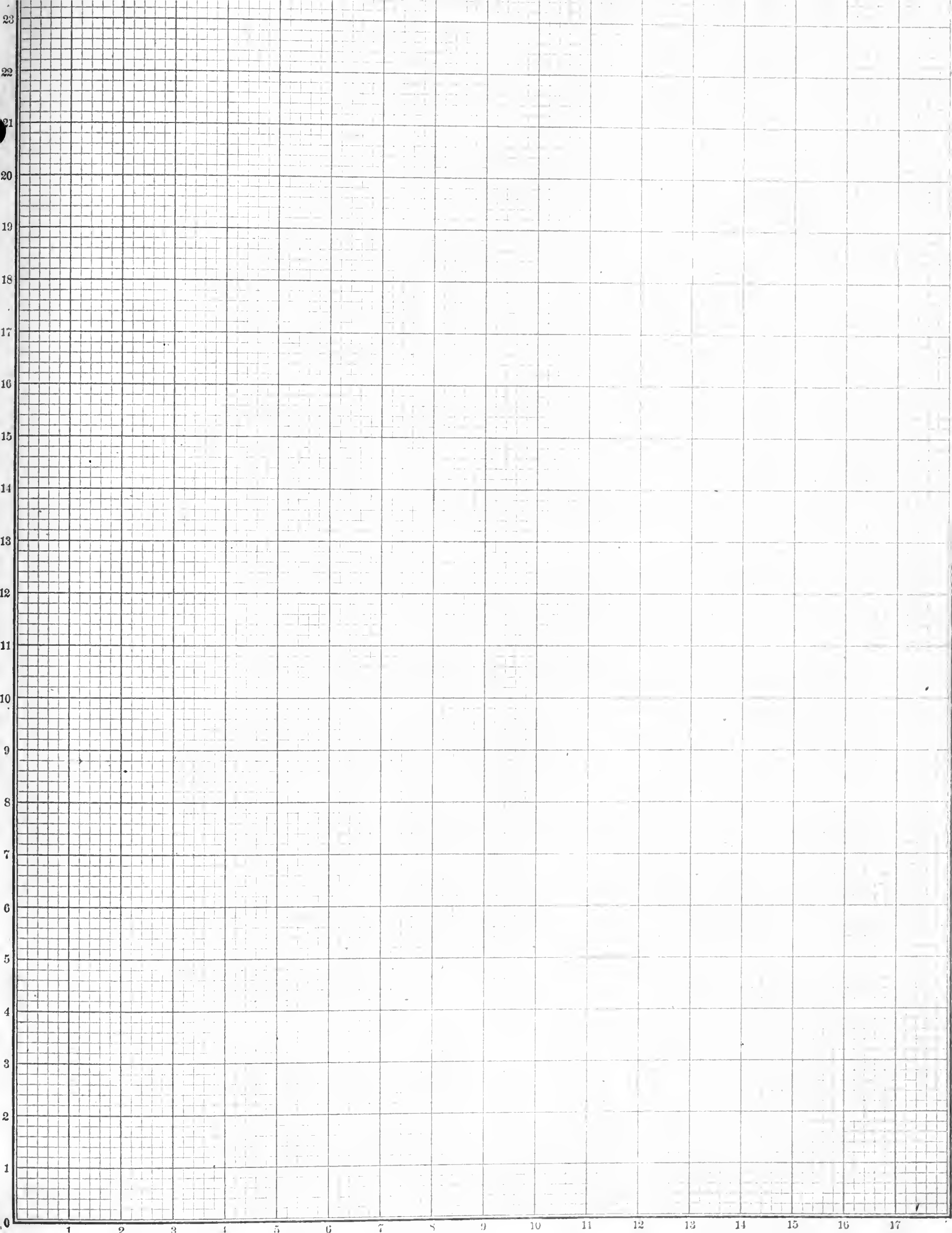
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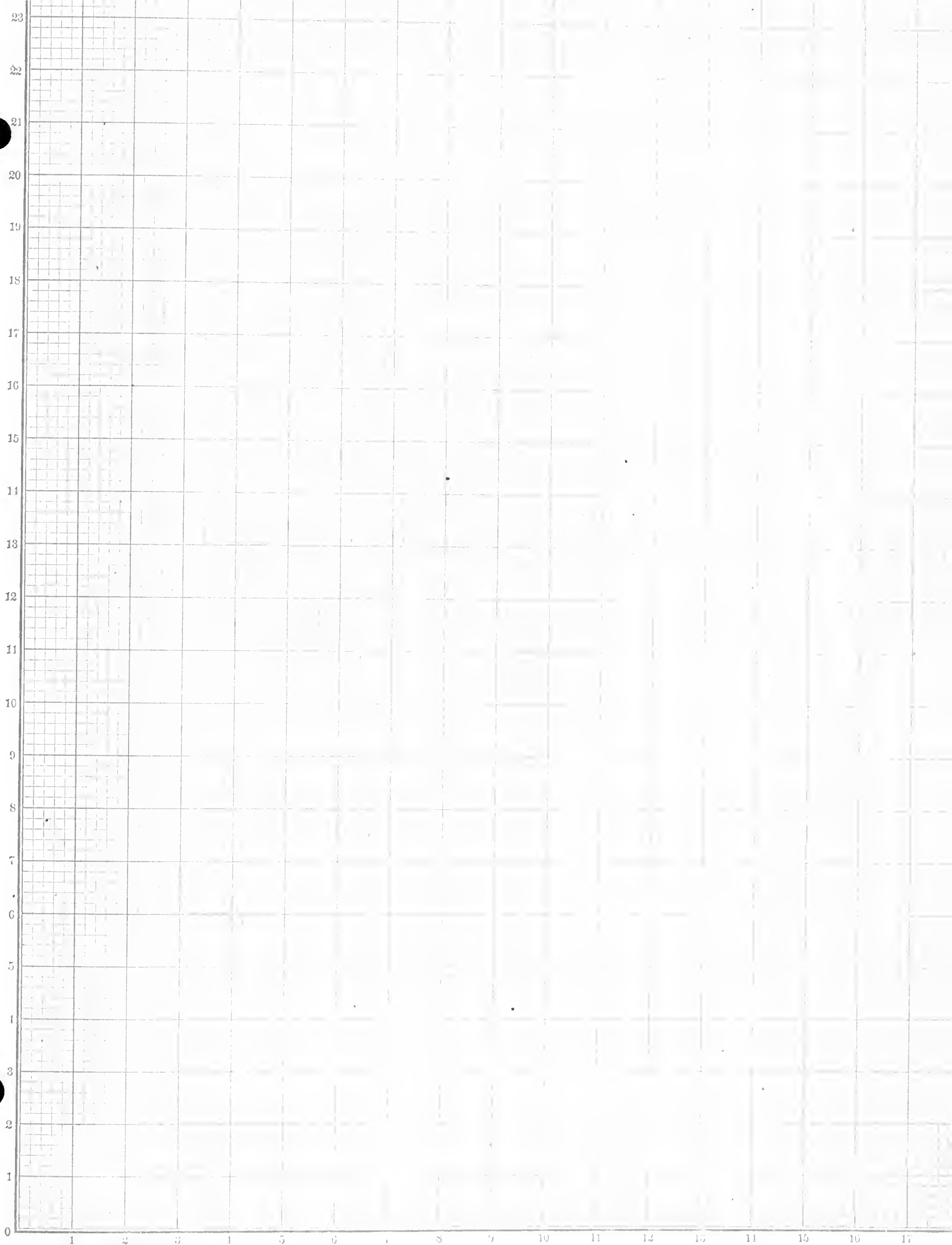

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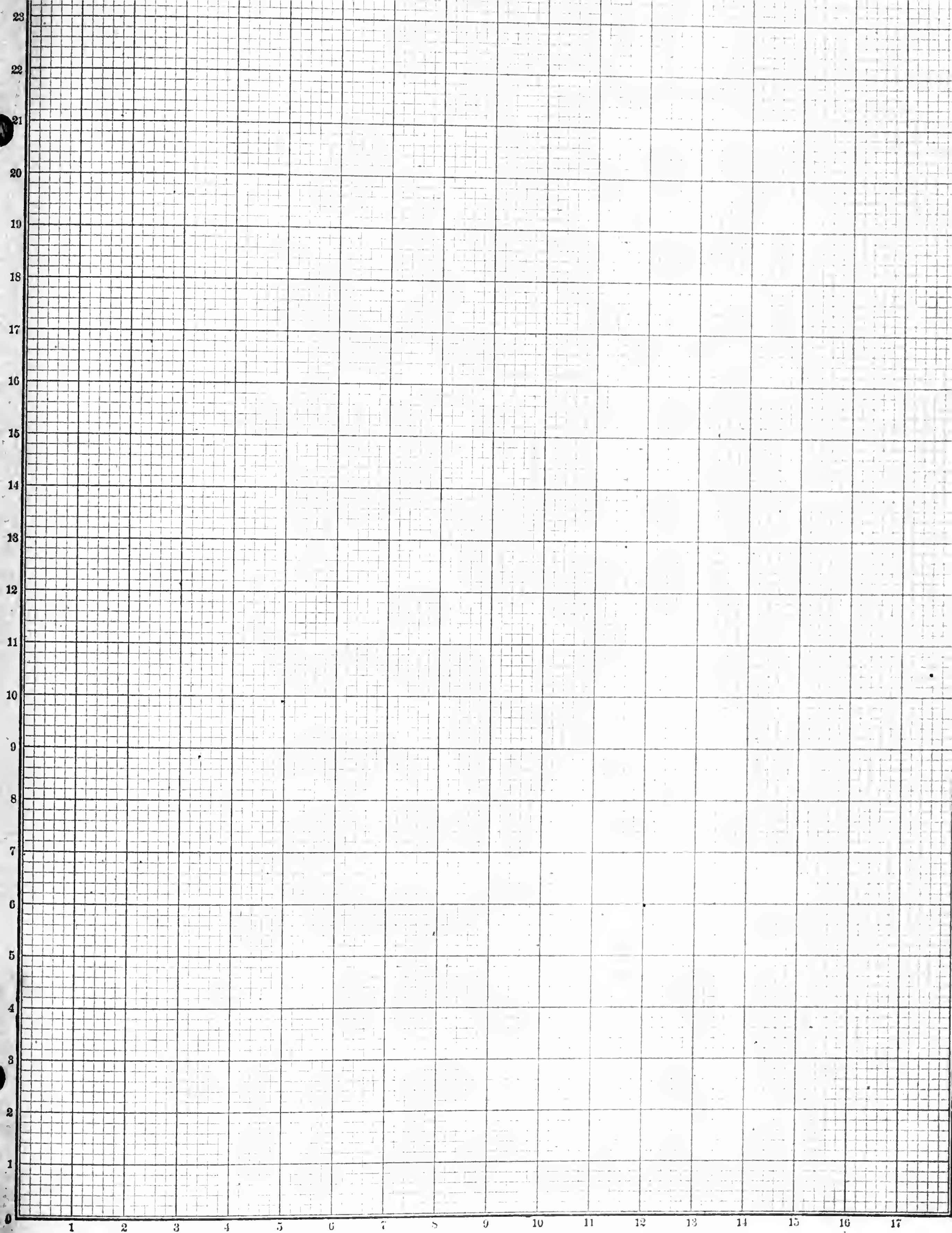
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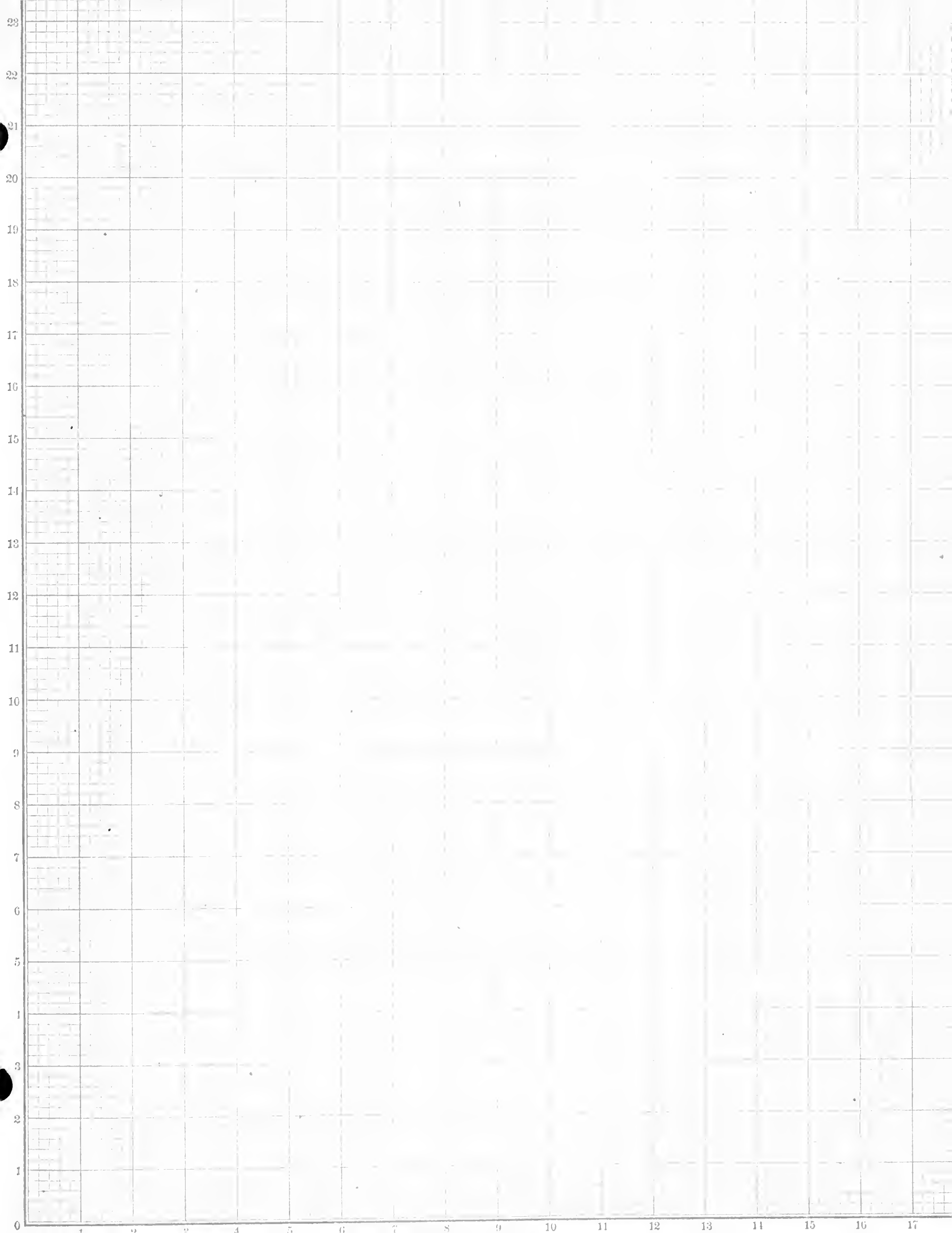
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